ESTABLISHING RULE BASED MODELS TO IMPLEMENT WORKFLOW WITHIN CONSTRUCTION ORGANIZATIONS

By

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Charles S. Duvel

This dissertation is dedicated to Alice Masteller.
Without her support and love this work would have never been possible.

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I would like to extend a heartfelt thanks to all of the construction company personnel and managers who provided so much of their valuable time and insight on their firms processes and offered me nearly unlimited access to their operations.

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Abstract of Dissertation Presented to the Graduate School
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ESTABLISHING ROLE-BASED MODELS TO IMPLEMENT WORKFLOW WITHIN CONSTRUCTION ORGANIZATIONS

By

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Major Department: College of Architecture

Because of the computer industry's lack of understanding of the construction trade and its particular needs for information, construction managers have been slow to take advantage of advanced information technology systems like workflow. The construction industry has not implemented systems to reduce the problems of information overload, delayed response and high overhead costs. This study examines and documents three different common management processes in the construction industry: labor reporting, request for payment, and change order request by utilizing process modeling for the purpose of identifying the rules necessary to automate those processes. The ultimate intent of this research is to assist researchers in developing rule bases for expert systems to support and control workflow that can be implemented in construction firms.

The study employed a multiple-case study research method in order to document the three processes at small sample of construction companies. A "domain expert" and the employees involved in the three processes under study at eight general contracting firms were interviewed as part of this research. Questions were asked about the three processes and the transcripts from these interviews were analyzed and decomposed to provide "as-is" activity diagram models of how these processes are completed in the construction industry and a set of basic "rules" for each process. The information gathered from the domain experts and individuals at each company was validated through the use of methods triangulation, whereby multiple methods of investigation are used to verify the accuracy of the data collected. These methods included the use of interviews, company documents and comparisons with the domain expert at each firm.

From the analysis of the information collected new, generic, "to-be" models of these processes were created. It was found that the processes can be reengineered, automated and controlled by using workflow technology supported by a rule based expert system.

CHAPTER 1
INTRODUCTION

This chapter begins by discussing the issues that led to this research. This is followed by statement of the research problem and a discussion of the purpose of this study. The research objectives of this dissertation are reviewed. The justification for this research is provided by the benefits and significance of the contributions of this research to the current management body of knowledge. The chapter closes by providing a summary of what is found in the remaining chapters of this dissertation.

Issues Leading to This Research

The past decade has seen massive changes in the US economy in the form of industry competitive structures, corporate business strategies, and within individual companies in the construction industry. A large portion of this change is due to the decreased cost and increased sophistication of information technologies, coupled with user friendly interfaces, that has made tremendous computing power available to the average person. Formerly huge data processing and number crunching tasks that could only be performed with mainframes can now be performed on laptop computers. A large number of companies saw their market share dwindle, their profits lost to foreign competition, or they lost out entirely to new competing technologies (Lipnack & Stamps, 1994).

Another major factor impacting the management of businesses during this time was the invigorated emphasis on total quality management or building a quality product by managers focusing work around core competencies to “achieve greater strategic focus, higher leveraging of human and fiscal resources, flatter, less bureaucratic organizations, faster response times, and vastly increased flexibility and morale in their organizations” (Quinn, 1992, p. xi). There was a realization by many business leaders that their firms were slow and unresponsive to the changes in the marketplace that were driven by consumers seeking quality. A common theme of current management books, according to Kobielus (1997) is that “hierarchical workflows [the norm in the construction industry] – the traditional corporate command, reporting, and review chain – lack the speed and flexibility necessary for success in today’s business world” (p. 17). More recently, meeting the ISO 9000 Quality standards, which simply mean “say what you are going to do, do what you say you are going to do, and show you did what you said you are going to do,” have become an essential prerequisite for successful competition in the global construction market.

While the majority of construction firms utilize some method of cost and schedule control on their projects many of these projects still suffer the effects of the inefficient flow of information due to bottlenecks, delays or bad or unrealistic data found in the historical database of the company (Abudayyeh & Rasdorf, 1991). As Tenah and Guevara (1985) observed “construction personnel require simple and concise information in an inexpensive form so that it is possible to optimize the effectiveness and efficient working of the organization and to make the maximum use of resources” (p. 493).

Figure 1-1 shows schematically the payroll recording process common to most construction firms. A close study of Figure 1-1 reveals that many opportunities for data entry error or other processing delay for payment due to human mistakes or intervention. Figure 1-2 shows how workflow tools simplify this process after reengineering. The expert system controller can advise the superintendent on proper classification of the craft worker's time and insure that information is passed on to the correct project manager and estimators responsible for the job. Other specialist skills can be built into the system for the superintendent or person entering the data using prompts, error messages and on-line help systems (Flowers, 1996).

Another area of concern are the problems caused by changes in management or office staff due to a number of problems such as turnover in management ranks, employee illness, vacations or new employees that are hired. Decision-making is slowed or stopped in the absence of employees familiar with company decision-making and business processes.

The nature of job performance has changed with the demise of functional departments and the empowerment of cross functional teams, particularly in large multinational firms. This has meant less direct management control. Narrow, task-oriented jobs have become more broad based to meet the requirements of the customer (regardless of their orientation of being internal or external customers).

Problem Statement

Construction managers are not taking advantage of advanced information technologies (IT) to solve the related problems of information overload, delayed response, and higher overhead because of a lack of understanding of what technology is available, how to implement workflow within their own firms and using it to its fullest potential. Mohan (1990) found that work done previously "has shown that expert-systems technology has the potential of offering practical tools for making intelligent and fast managerial and technical decisions" (p. 89). Despite this, in a survey completed for the trade magazine *Engineering News Record*, "many design firms and contractors have yet to embrace information technology even as its impact grows" (Phair & Angelo, 1997, p.30). As observed by Songer, Diekmann, Rojas, & Abdul-Hadi (1995) with the Construction Information Technology project group (CIT 21) "the majority of industry participants have been slow to embrace the use of new technologies" (p.195). The automation of business processes, "workflow," and its potential benefits, are not clearly understood by contractors because there has been no comprehensive study of the construction industry to document its different demands and needs for information technology. Songer et al. (1995) observed that contractors traditionally have been "reluctant to invest in new technologies until they are proven to be economically advantageous"(p. 193).

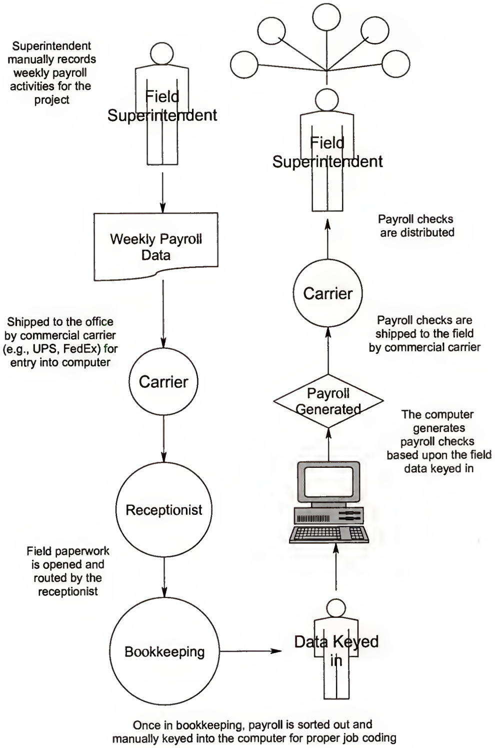
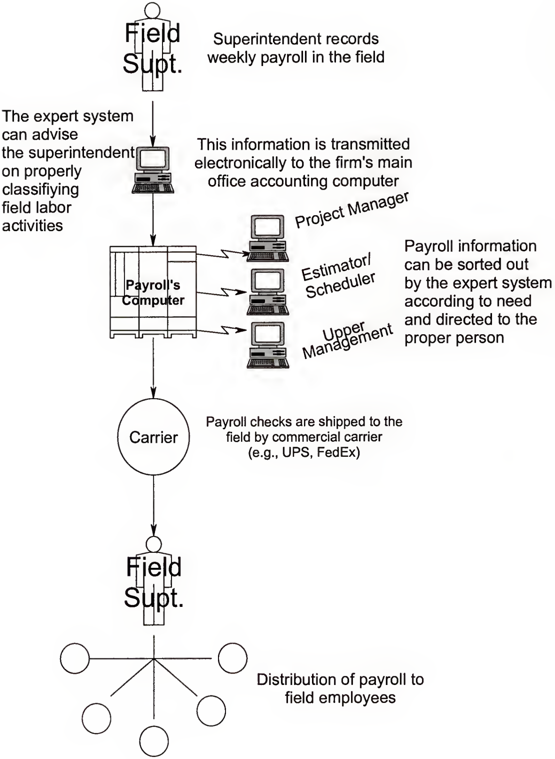

Superintendent manually records weekly payroll activities for the project
Field Superintendent
Weekly Payroll Data
Shipped to the office by commercial carrier (e.g., UPS, FedEx) for entry into computer
Carrier
Receptionist
Field paperwork is opened and routed by the receptionist
Bookkeeping
Data Keyed in
Once in bookkeeping, payroll is sorted out and manually keyed into the computer for proper job coding
The computer generates payroll checks based upon the field data keyed in
Payroll Generated
Payroll checks are shipped to the field by commercial carrier
Carrier
Payroll checks are distributed
Field Superintendent

Figure 1-1. Construction payroll reporting before reengineering and the application of workflow tools.



Superintendent records weekly payroll in the field

The expert system can advise the superintendent on properly classifiying field labor activities

This information is transmitted electronically to the firm's main office accounting computer

Payroll information can be sorted out by the expert system according to need and directed to the proper person

Payroll checks are shipped to the field by commercial carrier (e.g., UPS, FedEx)

Distribution of payroll to field employees

Figure 1-2. The new payroll process after reengineering and the implementation of workflow technology and expert systems.

Purpose of the Study

The purpose of this research is to explore and establish the theoretical framework and elements necessary to develop and implement a workflow program controlled by an expert system designed to effectively handle, monitor and document the transaction exchanges in the management operations of a construction firm. The examination will focus on three of the core, common, critical business reporting processes common to all construction firms: (a) payroll recording, (b) handling of change orders, (c) processing requests for payment by the owner. The development and application of an actual prototype will be left to others because of the rapid pace of the introduction of new technology, the need for a team of knowledge engineers, construction managers, and the customized needs and culture of the specific construction company.

Research Objective

Specifically, this research used process analysis modeling to examine, identify and document the typical reporting and document handling processes within the management of construction companies doing more than 25 million dollars in contract work and identified as either general contracting firms or construction management firms. This will determine what is necessary to successfully develop and implement the use of expert systems to control and automate business or workflow processes in construction management. From this will come a theoretical model of a rule base necessary for the development of an expert system to control the workflow program.

Benefits and Significance of the Research

The research provides a clear analysis of the basic business support processes of construction management firms in the United States with the intent of fully automating those processes after careful examination and modeling. The principal activities that are value added to those processes were identified and documented. Problems or shortcomings of the existing processes, selected for examination, were identified. The key components necessary for implementation of reengineered work processes, automated through workflow technology and controlled by an expert system, have been identified.

The major benefits of this research are its contribution to the reduction of overhead costs, reduced variation in performance and increase in the responsiveness of construction firms through the application of expert systems to automated computer-supported collaborative work processing tools, i.e. workflow. By planning workflow applications, which are controlled by an expert system, individuals and groups in both structured (office headquarters or regional offices) and non-structured environments (such as the job site) will be empowered to automatically manage events in a way that achieves the business objectives of the firm following the procedures developed by upper management. The problem of "sorting and selecting among the myriad of reports" for the information necessary for proper decision making faced by the managers in construction is eliminated (Tenah & Guevara, 1985, p. 493). Robin Flowers (1996) notes that "the introduction of computer-based systems . . . can be used to promote and impose standard processes and methods of working" (p.47). It is hypothesized that these tools will allow management functions, or other business processes, to be easily shifted throughout the firm with little or no regard to geographical location, time dependencies and minimal training. The use of these advanced methodologies in a construction company, particularly one with far flung national or international operations, is anticipated to be of strong interest because work assignments can be dynamically reconfigured depending upon the level of work or expertise required to complete the work. The elimination of geographical location, time dependencies and lessened training costs will then reduce the effects of these barriers and provide and promote greater efficiency and customer responsiveness by the construction management firm. Overhead will be reduced in firms of all sizes by reducing miscommunication, stream lining paper flow, cutting travel and package carrier expenses, and expediting decision making.

A further benefit provided to the construction firm is that their work processes will henceforth be documented for further study and self examination. Policies and procedures can be mated or aligned to specific job descriptions for meeting company objectives or needs. Changes can be made incrementally to meet the traditional conservative mind set of the construction contractor. Figure 1-3 provides a quick summary of the potential benefits of workflow implementation in construction with expert system modulated workflow.

Other benefits include the ability of contractors to better handle document control issues. Two kinds of records, shown in Table 1-1, must be maintained by contractors and others involved in construction:

Controlled records - which must be retained and are not changed at all

Revisable records - these are records that must have a clear revision level record

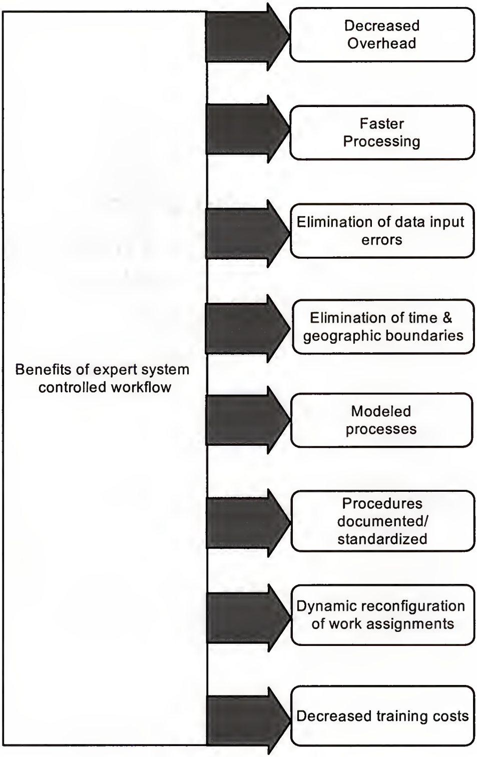

Benefits of expert system controlled workflow
Decreased Overhead
Faster Processing
Elimination of data input errors
Elimination of time & geographic boundaries
Modeled processes
Procedures documented/ standardized
Dynamic reconfiguration of work assignments
Decreased training costs

Figure 1-3. Summary of potential benefits of workflow in construction management.

Table 1-1. Examples of contractor records.

Examples of Controlled Records	Examples of Revisable Records
Test Reports	Blue Prints
Inspection Reports	As-built drawings
Purchase Orders	Shop drawings
Labor reports	Inspection instructions

Intelligent, rule-based controlled workflow systems provide a means for handling both of these types of records seamlessly, behind the scenes, with little intervention or adjustment from the systems administrators once they are set up properly.

Organization of this Study

Chapter 1 states the purpose of this study, provides a sense of motivation for why this topic is important to investigate, and discusses the contributions made by this study to construction managers. This section will briefly describe the organization of the dissertation in Chapters 2 – 6 and the appendices.

Chapter 2 – Literature Review – reviews a cross section of the literature by introducing the historical context of workflow and how it can be used. A discussion and explanation of expert systems is provided and some examples of expert system programs that have been developed for construction specific applications are reviewed. Chapter 3, Methodology, contains a description of the qualitative methodology employed in the study, contractor selection, and validation procedures of the results found during process modeling. Chapter 4, Analysis of the Data, provides a summary analysis of the interviews conducted as part of this research and proposed generic workflow process models developed from those interviews. Chapter 5, Conclusions of the Study, highlights the contributions provided by this study, presents the process models developed and discusses the limitations of the study. In Chapter 6, Future Research, the researcher examines three areas of potential research. The appendices include the list interview questions, the interview agenda, side by side comparisons models of the company's processes under study, the workflow "to-be" process models as developed by the researcher, and a biographical sketch of the researcher. The case studies developed as part of this research are presented as Appendices G - N. Each case study is designed to be self contained in that the "as-is" processes of the companies studied are presented along with "to-be" models and an analysis of the information found in the case.

CHAPTER 2
LITERATURE REVIEW

In this chapter the concepts of workflow are explained and the historical context of workflow is provided in terms of other information systems. As part of this discussion, an examination of different process modeling techniques is conducted and the process by which modeling may assist in the proper development of workflow systems is previewed. A discussion of expert systems, their position in the realm of artificial intelligence and an explanation of how they work is also included.

The Historical Beginnings of Workflow

By the early 1980s a number of different scientific and academic fields, including psychology, computer science, and social science, were studying the interaction between employees in an office setting and how they were using their computers for decision making analysis and document control. In time, the term "Computer-supported cooperative work" (or CSCW) was developed by Irene Grief (at MIT) and Paul Cash (with Digital Equipment Corp) in 1984 to describe this collection of ideas and concepts (Santos, 1995). CSCW has been defined by Wilson (1991) as "a generic term which combines the understanding of the way people work in groups with enabling technologies of computer networking and associated hardware, software, services and techniques" (p.7). With the explosive growth in the use of the personal computer in the business workplace, information technology (IT) specialists have conducted significant research and development into how computers and computer networks could be used to assist groups of people working together.

IT experts have developed the name "Groupware" to describe the collective software and hardware used for collaborative computing by people. Groupware technologies are systems that offer networking, storage, graphical display, and information organizing functions combined with capabilities for collaborative computing.

Generally speaking groupware is divided into three main categories, document and form based communication, data and transaction communication, and organization communication. This is more clearly shown in Figure 2-1. Groupware technologies enhance the communication and interaction among workers. E-mail, hypertext, or hyper media and electronic white boards are all examples of groupware technology. Hypertext allows users to access text information stored in a database in non-sequential order. Hypertext is a simple mechanism of electronic nodes connected to each other through links. When the nodes are used for storing information in different media other than text, like video or audio, then the application is referred to as hypermedia (Mahapatra & Courtney, 1992). Electronic whiteboards are similar to dry-erase boards except that everything written on the electronic whiteboard can be saved by the user to a computer image file which can be printed, sent as an e-mail attachment or stored as a meeting record. More sophisticated electronic whiteboards, known as PC-interactive boards, can be used as a touch sensitive monitors that allow interaction with a computer when used in conjunction with an LCD projector. Probably the best known groupware tool is the product Lotus Notes®, which allows a group of people to share common information created in personal productivity applications such as word processors and electronic spreadsheets.

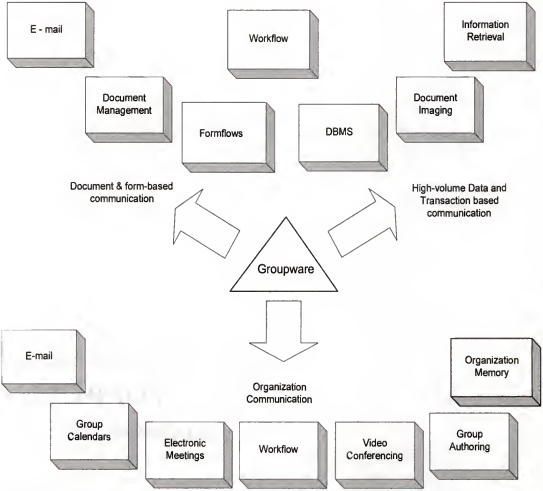


Figure 2-1. Groupware categories (from Koshafian and Buckiewicz, 1995). Copyright 1995 by John Wiley and Sons, Inc. Adapted with permission.

The most recent development in groupware technology has been the increased use of local area networks (LANs) and wide area networks (WANs). LANs, shown in Figure 2-2, are computers linked together through cabling; they cover a limited geographical area like the floors of an office building. WANs cover large geographic areas, even continents, and utilize a number of different hardware and software components.

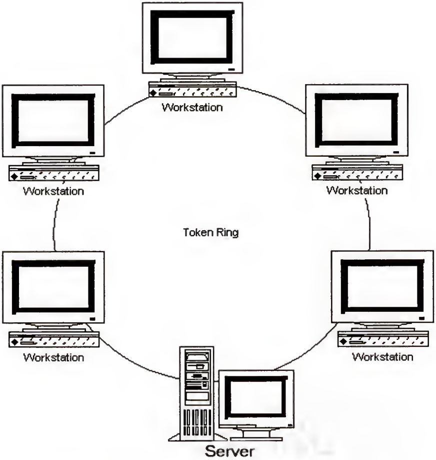


Figure 2-2. Example of a local area network (LAN).

Yet another recent development in groupware are performance support systems. These support systems are defined by Reynolds and Araya (1995) as:

> An integrated computer program that provides any combination of expert system, hypertext, embedded animation, CAI [computer assisted instruction], and hypermedia to an employee on demand. Performance support systems allow employees to perform with a minimum of support and intervention by others. Examples include help systems, electronic job aids, and expert advisors (p. 3).

Additionally, performance support systems may be run or maintained by expert systems (a branch of artificial intelligence). Expert systems are discussed more fully in a later section of this chapter.

The Paperless Office

Another goal of businesses and information technologists in the 1980s was the attempt to develop document imaging systems to eliminate the need for paper. In fact the earliest workflow systems were designed with the goal in mind of converting paper-based information into digitized documents. It was recognized that paper forms and form routing that required manual sorting could be done electronically with substantial gains in processing time and efficiency (Khoshafian & Buckiewicz, 1995).

Fellows (1994) has observed:

> Construction management involves the transfer and processing of a very large quantity of information. . . current practice is not taking full advantage of the use of electronic methods to speed, simplify and extend this information flow. In one project, a mountain of paper moves backwards and forwards from one entity to another being continually interpreted, added to, re-written and sometimes reduced (p. 163).

This practice is still the norm in most construction offices despite the development and successful establishment of workflow systems in other industries such as banking and insurance. As Mincks and Johnson (1998) have commented:

> Much of [the construction] industry's paper work is repetitive in nature, in that the type of form or reason for using the document will be accomplished many times during the project. Only a few forms are used during the project. Many of the contractor's operations are duplicated month after month, using the same format, but different data. 'Application for Payment' is a process that happens month to month, using the same form, but changing data. . . . Integration of information could produce usable project management information in addition

> to billings, payments from owner, and keeping track of monies owed to subcontractors (p. 301).

The amount of paperwork and information flow is too great for construction professionals to keep up with the tidal wave of paperwork and information generated from the large modern construction project site. Tenah and Guevara (1985) have noted that, while the full information is tempting the construction firm will fail to operate efficiently because, "construction personnel may be flooded with information they do not need to do their work, to the point that they cannot concentrate on the information they [do] need" (p. 493). Chen and Li-Jun (1996) found in their study of the construction industry:

> A great amount of information will be produced at any time in the construction progress. It is too difficult to collect, process, store and transmit them immediately and exactly. In order to manage the information of the engineering progress, investment, quality, contracts, [and] documents completely, systematically and rapidly, it is necessary to make a MIS [management information system] of controlling and managing with [the] computer as its centre (p.3).

Workflow

Workflow is considered to be an extension of a set of tools for information technology collectively referred to as "groupware." The term "workflow" is broad-based with differing meanings depending upon the perspective of the individual (Thé, 1994).

Despite many attempts to describe workflow, no single definition of the term "workflow" has been agreed upon, although several have been offered. From a strictly process management point of view, workflow is seen as a unit of work that repeatedly occurs in an organization. Thomas Schäl (1996) defined workflow as:

> a unit of work generating products or services which are related to, or result in, customer satisfaction. Every workflow has a main customer, who is served by a supplier, or a co-operative network as being a chain of customers and suppliers, working towards the satisfaction of the main customer (p. 12).

The perspective of information technology specialists in the definition provided by Ronni Marshak, a consultant with the Patricia Seybold Group, may summarize it best. Marshak, as quoted by Koshafian and Buckiewicz (1995) defines workflow as:

> Simply put, workflow is the automation of the processes that we use every day to run our business. A workflow application automates the sequence of actions, activities, or tasks used to run the process, including tracking of the status of each instance of the process, as well as tools for managing the process itself (p. 208).

This process of automation may be based on the use of e-mail or some other type of electronic media that allows for collaborative work processing. According to Khoshafian and Buckiewicz (1995) the main focus of workflow technology is to provide "tools that empower individuals to manage business activities and events" (p. 209). The goal of workflow software, as noted by Aldred (1994), is to channel and control people in such a way as to "maximize" their efforts in contributing to the business (p. 62). Different types of workflow tools are shown in Figure 2-3.

A workflow within a company can be viewed as a series of actions, tasks or events that form a business process (Chaffey, 1998). A commonly provided process example is loan approval in a bank. Each task in loan approval is decomposed into the individual work items that must be completed as a part of that activity. Completion of each work item requires the use of resources (human or machine). The arrangement and method by which the work items are performed are governed by business rules.

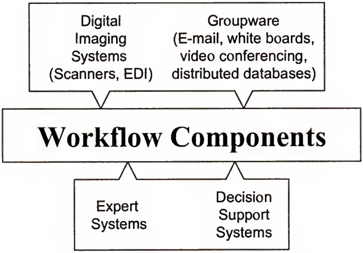


Figure 2-3. The different parts of workflow.

Classifications of Workflow

The concept of workflow also is made difficult to comprehend by differences in how people manage the flow of work within a computer network system. Workflow classification is complicated further by the different types of organizations using workflow: organizations may have either *functional* structures or *process* structures. As Barrie (1981) has observed, the traditional approach of the construction industry has been to develop firms using the functional organizational hierarchy as shown in Figure 2-4.

Carr and Johansson (1995) found that the functional approach to management organization has a tendency to develop department "silos" which make it more difficult to recognize who has "ownership" over an internal company process and therefore more difficult to reengineer the process. The concept of reengineering is discussed further in a later section of this chapter.

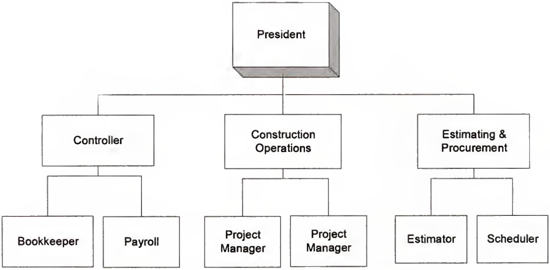


Figure 2-4. Typical organizational layout for a construction firm.

Workflow applications are generally separated into three specific categories, as proposed by International Data Corporation (IDC), depending upon the particular application (Khoshafian & Buckiewicz, 1995; Marshak, 1995). Note that these categories, shown in Figure 2-5, provide for much overlap or common features in terms of how they may be operated (for example relying heavily on the use of e-mail) or how they are used (such as for both administrative and production process workflow). These workflow taxonomies are:

1. **Ad hoc** workflow (for temporary situations or where less well defined steps are involved).
2. **Administration** workflow (used in areas for routine tasks such as purchase orders and travel expense reporting).
3. **Production** or transaction based workflow (used in areas that are rigorously structured and in automated business procedures).

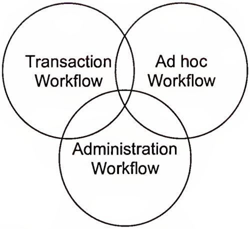


Figure 2-5. The taxonomies of workflow.

Ad hoc workflow is used for projects or operations that are exceptional to the usual operations of the firm. In ad hoc workflows teams are put together for a very specific purpose and after completion of the project are returned to their normal operating areas. A fast-track industrial plant project would be an example of this type of workflow process. Employees from estimating, procurement, finance, construction, and engineering departments of the contracting company, and the owner's representative, and maintenance people may be brought together to work very intensely on the project until completion. Once the job is finished, these employees may return to their normal operational areas where they will be assigned to a new project with different employees from other departments. Another example is the hiring of a new employee.

Administrative workflow is typically developed for applications that are common and routine and have very standardized formats. Typical examples include: (a) vacation or leave requests, (b) reimbursement for travel expenses, (c) vendor listing forms, (d) salary or wage changes.

Administrative workflow systems provide for the automatic routing of the documents after they have been properly filled out. Electronic “signatures”and notification alarms are other specialized functions commonly found in administrative workflow systems.

Production workflow is characterized by the need for an audit trail because of the financial risk to the company. Some common examples of production workflow functions in construction operations include: (a) purchase orders and payroll, (b) request for payment, (c) change orders, (d) vendor or subcontractor performance evaluations.

Because of the financial and legal exposure of the firm, procedures and processes are usually very detailed and specific as to the information to be provided and in what fashion. Tasks or processes that are commonly considered production workflows are normally followed “day to day with very little change; they are frequently occurring transactions” (Khoshafian & Buckiewicz, 1995, p. 223). Very often, the steps and the results of these processes are of “high value” to the company. For example, missing information on a request for payment may cause it to be denied or returned to the contractor for completion, creating serious consequences in cash flow.

Workflow in Total Quality Management and Business Process Reengineering

Workflow is closely identified with business process reengineering (BPR) in which business processes are re-conceptualized (Gantz, 1993). Business process reengineering has been described by a number of different terms including Business Engineering (BE), Business Reengineering (BRE), Business Process Engineering (BPE) or Business Process Design (BPD) (Hammer & Champy, 1993; Marshak, 1995; Spurr, Layzell, Jennison, & Richards, 1993).

Davenport and Short (1990) defined a business process "as a set of logically related tasks performed to achieve a defined business outcome" (p. 12). From the industrial engineer's standpoint, Melan (1993) defines a process as "a bounded set of interrelated work activities each having prescribed inputs and outputs" (p. 14) with a definite beginning and end.

The concept behind BPR, according to Colberg et al. (1995) is to examine the business processes and to "eliminate activities that do not add value for the customer" (p. 34). Figure 2-6 shows some of the non-value added activities that may be eliminated in re-engineering business processes through the use of workflow technology.

The Business Process Model and the Implementation of Workflow Systems

The implementation of any formalized workflow process system begins with modeling the existing process by developing a "as-is" snapshot of the company's systems. The application of workflow redefines the flow of documents and tasks within the firm with the intended goal of improving the overall quality and productivity within the firm (Avedon, 1995). Back and Bell (1996) observed that "a process that spans cross-functional and interorganizational boundaries . . . will benefit from higher levels of information integration" (p. 13).

A major tenet of Total Quality Management's (TQM) philosophy and methodology is the focus on employee involvement for quality and customer satisfaction (Graves, 1993). Several key advantages for TQM are achieved when utilizing workflow including:

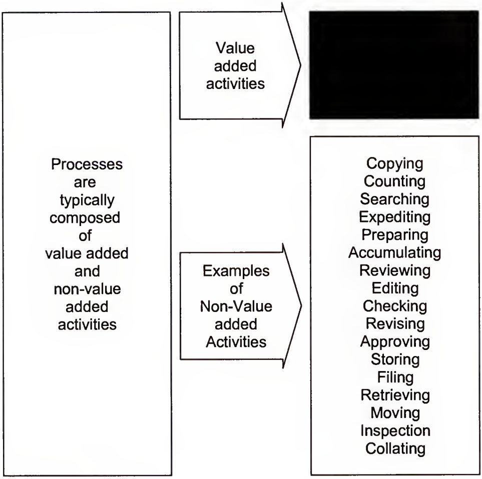


Figure 2-6. A look at non-value and value added activities typically found in a process. From Colberg et al. (1995). Copyright 1995 by John Wiley and Sons, Inc. Adapted with permission.

1. standardizing and documenting TQM procedures and systems within a geographically dispersed company like a construction firm and its job sites. This is shown in Figure 2-7.

2. increasing validity or degree of conformance of data to the business rules (English, 1999).

The concept behind process modeling is to ensure that problems within the process are identified so they are not repeated and the process itself is understood (Cichocki, Helal, Rusinkiewicz, & Woelk, 1998; Davenport & Short, 1990; Gerrits,

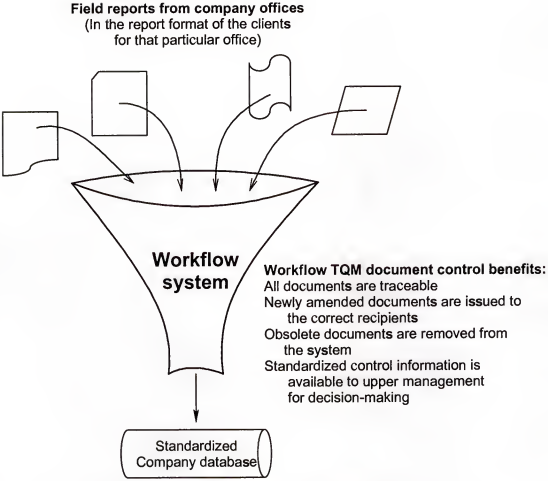

Field reports from company offices
(In the report format of the clients
for that particular office)
Workflow system
Workflow TQM document control benefits:
All documents are traceable
Newly amended documents are issued to the correct recipients
Obsolete documents are removed from the system
Standardized control information is available to upper management for decision-making
Standardized Company database

Figure 2-7. Workflow TQM document control benefits.

1994; Hammer & Champy, 1993). Clearly defined process ownership and ownership requirements must be identified.

Processes that cross several function lines often have ambiguous ownership. The example shown in Figure 2-8 illustrates a typical problem of process ownership within a construction firm.

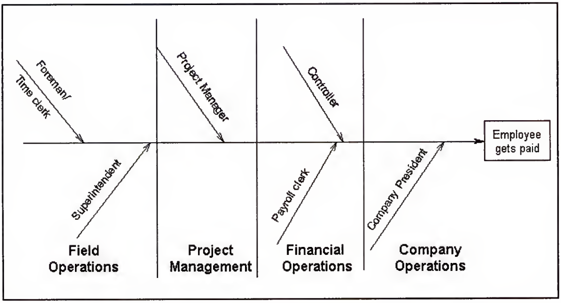


Figure 2-8. Who "owns" the process of employee payroll when it crosses department function boundaries?

The business process model (BPM) serves two critical purposes:

1. displays the proper separate routing of information/data/documents in the correct order and sequence in which people need to handle the information.

2. graphically displays the tools, or applications necessary, for processing the information for each task.

The model also provides an easy to grasp graphical representation of the activities, the dependencies among the activities and the human or information system skills that are necessary to the process of transforming the inputs into useful output (e.g., time sheets transformed into payroll checks) (Cichocki et al., 1998).

Davenport and Short (1990) and Cichocki et al. (1998) have both emphasized that accurate measurement of the existing model process serves as the baseline for future improvement and for estimating workflow performance level. In order to develop these models in construction contractors's offices were visited and their processes modeled. The process method used for this research is explained in Chapter 3.

Melan (1993) has suggested that three attributes serve as the principal criteria for evaluating a process, shown in Figure 2-9. Effectiveness is used to measure the output of the process in succeeding in meeting the customers needs. *Efficiency* is used as the measure to determine the productivity or utilization of resources by the process operation. In effect "the output and resources required to achieve the output" are measured in terms of efficiency (Melan, 1993). *Adaptability* of the system process to change is a critical element to measure because changes in technology and required output may occur.

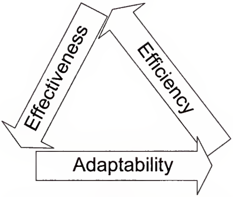


Figure 2-9. Measures of process effectiveness.

The BPM is the tool used in the design step to ensure that the structure of the various objects involved in the procedures, processes, and projects of the firm are properly identified. The BPM also serves as a model of the information flow between various departments, roles, groups, and workers. Identifying the participants of the workflow process is important because tasks, sign-off, and security functions are assigned to users within the system.

Development of the Business Process Model

Melan (1993), suggests that the development of the process model for establishing workflow is usually broken down into three phases as shown in Figure 2-10.

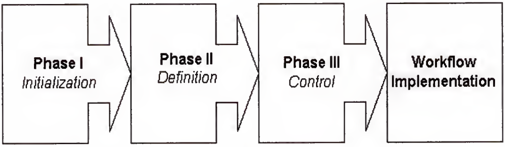


Figure 2-10. The three phases of process management.

Phase I: *Initialization* - Here process ownership is established and interface boundaries (the starting point and ending point), sign-offs, and approvals are identified. The factors that influence performance (e.g., reporting requirements, managerial styles, company culture, etc.) also are determined.

Phase II: *Definition* - During this phase the baseline of the process is established for use in future measurements. The processes under study are modeled or mapped utilizing some symbolic description method like flowcharts or data flow diagrams.

Phase III: *Control* - In this phase of process management modeling, the control points and measurement criteria are established. In industrial processes this would be quality control conformance inspection and testing. In a service business measurement criteria may be customer complaint feedback.

Abudayyeh and Rasdorf (1991) have suggested a four-step modeling schema, shown in Figure 2-11, specific for construction management systems. Similar to Melan

(1993), and Davenport and Beers (1995), Abudayyeh and Rasdorf also identify Step 1 as process identification and definition. Abudayyeh and Rasdorf identify Step 2 as conceptual modeling or development of the process model.

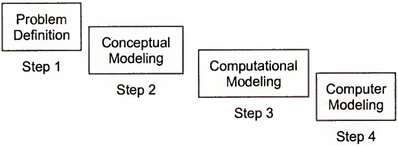


Figure 2-11. The proposed modeling schema of Abudayyeh and Rasdorf (1991).

According to Roos and Bruss (1994) the concept of process modeling had its beginning in manufacturing with the father of modern scientific management, Frederick Taylor, in the early 1900s. Since that time a number of different formalized process mapping schemata have been developed including flow process charts, process charts, process flowcharts, and flow diagrams Melan (1993). Newer methods include role activity diagrams (RADS) described by Huckvale and Ould (1995) and Ould (1995). Another method is the Integrated Definition for Function Modeling (IDEF) method created for the U.S. Air Force as reported by Hunt (1996).

The basic concept behind all of these methods is to graphically display the work being completed, the data flow, and in industrial processes, the materials used. Through mapping the business processes under study can be reengineered and workflow information technology implemented.

Significant debate exists regarding the level of detail the process model should include. Hammer and Champy (1993) and others, (e.g., Gerrits), argue that the BPM need not be a detailed model of the businesses' processes as the intent is to eliminate the existing process. However, according to Busby and Williams (1993), the business processes must be decomposed enough to provide the identification of the process elements and to allow the modeler to correctly "describe activities and their relationships" (p. 2183). The process elements are what I. T. Hawryszkiewycz (1994) has labeled the "business artifacts" (e.g., checklists, forms, memoranda, reports, etc.) or the roles, agents, and activities that make up the process.

The paper "Process Modeling," presented by Curtis, Kellner and Over (1992), although primarily concerned with the process of modeling software development, provides guidelines to the underlying concepts of process modeling. Huckvale and Ould (1995), suggest that four underlying concepts are used for process modeling and include the following basic views to understand the questions people want to ask about the process. These four perspectives are (a) functional view; (b) behavioral view; (c) organizational view; and (d) information view.

Functional view – has what activities are performed and the data flows from these activities. This type of view is often shown as a Data Flow Diagram as shown in Figure 2-12. IDEF0, developed by the Air Force is another type of model technique providing a functional view of a process. Models of this type are what Aouad et al. (1993) label as "data models." Other names for these models include Structured Analysis Method (SAM) diagrams and Structured Data Analysis (SDA) diagrams (Fisher, 1991). The problem with these types of models according to Björk (1992) is that the data flows tend to become quite large very quickly when there is significant two way communication. This makes understanding the models more complex.

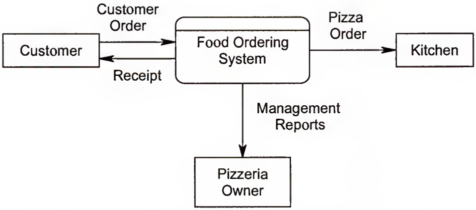


Figure 2-12. Sample data flow diagram of the pizza-ordering process.

Behavioral view -- examines the conditions under which activities may be performed or what activities may be performed. An example of a process modeling technique with a strong behavioral view would be the Role Activity Diagrams as developed by Holt, Ramsey and Grimes (1983).

Organizational view – shows the participants of the process along with the communication mechanisms, and displays storage media. Process maps similar to traditional flow charts are an example of the organizational view of process modeling.

Informational view – examines the documents and data produced or manipulated during the process. Typically, models developed to present this type of view are used where the documents are relatively standardized, such as Electronic Data Interchange (EDI) documents for order fulfillment between organizations like a grocery store and its warehouse. The Entity Relationship Attribute (ERA) modeling method as described by Chen (1976) exemplifies the modeling technique that provides this view.

Process Modeling in Construction Management

Soares and Anderson (1997) found that business processes within the construction industry have either a company or project-level focus. In their view, construction companies have two types of processes: production and administration. Either function may be performed in the field or at the office. Soares and Anderson state that company-level processes are designed to support the organizational operations of the company that are necessary to maintain the business. Examples of administrative processes in the office are marketing or estimating. An example of a field administrative process would be determining job progress. Examples of office production processes include designing a retaining wall or calculating heat transfer through a wall. An example of a field production process would be steel erection.

Björk (1992) has described the three major approaches to information modeling in construction as data modeling, activity modeling, and product modeling. Cichocki et al. (1998), have taken a different approach and separate into three broad categories the types of process modeling as shown in Table 2-1. It must be remembered that in developing a process or workflow representation parts of all three methods may be used simultaneously in order to develop the complete picture. The particular circumstances of the process under study will dictate the selection of the type of model to develop.

Table 2-1. Types of process modeling.

Communication-based methodologies	This methodology represents an action based on the communication between a customer and company representative.
Artifact-based modeling	This methodology represents objects (invoices, customer orders, etc.) that are created, modified and used during the process.
Activity-based modeling	This methodology focuses on the decomposition of work activities of the people and equipment they may use in the course of the process.

Introduction to Expert Systems

This section of the research serves as an introduction to Expert Systems by providing a discussion of what they are in terms of artificial intelligence, a little of their history, some explanation of how the rule base is created through an explanation of the expert system reasoning process. The end of this section provides background on expert systems benefits for the construction contractor.

Expert systems are one of the four main branches of artificial intelligence as seen in Figure 2-13 (Finn & Reinschmidt, 1987; Pedersen 1987; Pedersen, 1989). Expert systems are programs that use a human expert's knowledge and inference techniques to solve problems in a specific domain.

History of Expert Systems

Expert systems have had a relatively short history. Jackson (1986), has stated that the "classical period" of artificial intelligence (AI) research began in 1950 and ended

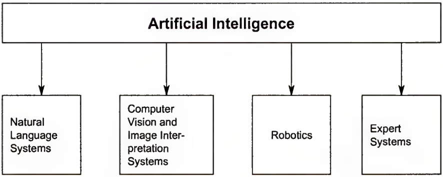


Figure 2-13. The four branches of artificial intelligence.

about 1963 or 1964. Yet others (e.g., Beynon-Davies, 1991) consider AI research being formalized in 1956. However, the first, true, expert system, DENDRAL, which could infer a structure of molecules by mass spectrography data, was created in 1963 at Stanford University (Beynon-Davies, 1991; Bramer, 1982; Liebowitz, 1988).

Since that time a number of expert systems for solving specific problems have been developed for use in medicine (e.g., MYCIN for the treatment of blood infections) and for other fields like insurance, banking, engineering, and construction (Badiru, 1992; Ernst, 1988; Maher & Kostem, 1987; Turban, 1995; Watkins & Eliot, 1993). Some examples of rule based expert systems in construction are shown in Table 2-2.

The earliest expert systems such as DENDRAL used traditional computer languages such as LISP to build up a "rule base" (Beynon-Davies, 1991). However, the most powerful expert systems are the ones containing knowledge that is gathered over time. These systems are refined and improved by the users until they can exceed the decision making ability of the human domain expert.

Four major methods (formal or classical logic, semantic nets, frames, and production rules) to represent the domain knowledge of a given subject have been

Table 2-2. Expert systems developed for construction applications.

Program Name	**Description of Program**
Pump-Pro	(developed by Stone & Webster, Inc.) a diagnostic program designed to aid pump mechanics, millwrights, etc (Finn & Reinschmidt, 1987).
HI-RISE	an expert system used to perform preliminary structural design of high rise buildings by developing feasiblity alternatives for lateral loading (Nguyen, 1989).
A Knowledge based Expert System for Concrete Mix Design	this program was developed using the expert system shell EXSYS Professional and the spreadsheet program Quattro Pro to assist the user in concrete mix design (Bai & Amirkhanian, 1994).
MASON	a rule based expert system that provides estimates of masonry construction productivity and advice for concrete block and brick masonry in commercial construction (Hendrickson, Martinelli, & Rehak, 1987).
Construction Planex	an expert system for construction project planning that generates activity schedules for the excavation and structural erection of concrete and steel framed buildings (Zozaya-Gorostiza, Hendrickson, & Rehack, 1989).
MODEX	a knowledge based expert system created to assist engineers in modularization design decisions for industrial and commercial project facilities. Financed by the Construction Industry Institute (Murtaza, Fisher, & Skibniewski, 1993).
SmartDoc	a knowledge based expert system designed to develop a set of conditions for construction contract documents (Rocha & Morad, 1993).
KYBAS	an expert system designed to assist in the analysis and design of highway bridges. It uses Fortran modules to design the beam sizes and then interfaces with C to provide simple code interface for the user (Fenske, Cassaro, & Ragade, 1991).
A Knowledge based adviser to Diagnose Defects in Flat Roofs	a program developed by researchers in the United Kingdom to provide for diagnosis of defects in flat roofs on buildings; program can diagnose up to 276 different defects in the roof system or roofing details and has nearly 1000 rules built into the system (Allwood & Goodier, 1995).

developed (Brulé & Blount, 1989; Liebowitz, 1988; Sparrow, 1998). The most widely used technique to represent knowledge in the knowledge base is through the use of production rules written in IF - THEN or SITUATION - ACTION statements (Efstathiou, Mamdani, & Bohanec, 1984).

The underlying concept that led to the use of production rules in this form of representation came from the observation that human experts often think in IF - THEN patterns when solving a problem (Chadwick & Hannah, 1987). The following example may make this more clear. Assume that a person gets in his/her car, turns the ignition key, and the car does not start. A simple IF - THEN example situation may look like the following:

IF Car does not start
THEN Check starter
IF Starter does not work
AND The headlights are dim
AND The ignition and oil pressure lights do not come on
THEN Battery may be dead

The use of production rules provides several major advantages in that the syntax of IF-THEN statements is very simple, the rules are easy to understand, and the knowledge base can be quickly expanded or maintained (Turban, 1995).

A number of definitions have been proposed for rule based experts systems (Doukidis & Whitley, 1989). However, rule based expert systems are recognized by four major features summarized in Table 2-3 (Beynon-Davies, 1991).

Table 2-3. Features of rule based expert systems.

1. The system deals with subject matter of such complexity and specific domain that normally a human expert is required to make decisions.
2. The expert system has the ability to perform at the same level as the expert through the use of rules or other structures that contain the knowledge and experience of experts.
3. The system should incorporate a methodology for handling uncertainty to provide for logical inferences and interpret ambiguous facts or imprecise knowledge.
4. The system must have the ability to provide an explanation or justification to the user for conclusions the program has developed.

The Inference Mechanism

The expert system uses a “motor” or “inference engine”to control the actions taken by the system to determine which rules are applicable to the given situation. As the inference engine identifies rules that fit, it applies or “fires the rule.” Figure 2-14 shows parts of the rule-based system.

The inference engine is a software module that is part of the expert system. It is programmed to process the rules from the domain knowledge stored in the knowledge base (Finn & Reinschmidt, 1987; Pedersen, 1989). The process of developing the knowledge base, or “the rule base,” is discussed in a later section of this chapter.

The inference engine processes the domain knowledge to reach new conclusions (Savory, 1988). The inference engine resolves any conflicts between rules, activates the chosen rule and evaluates the results for further action (Klahr & Waterman, 1986; Nebendahl, 1988). In forward chaining expert systems the inference engine can provide the user with the probability of the effectiveness of the decision based upon the information provided and the rules applied.

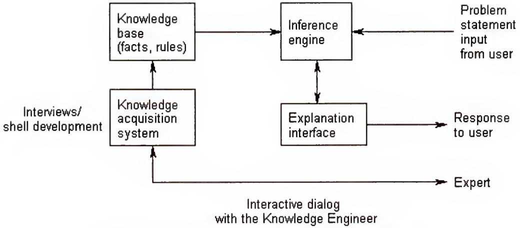

Knowledge base (facts, rules)
Inference engine
Problem statement input from user
Interviews/ shell development
Knowledge acquisition system
Explanation interface
Response to user
Expert
Interactive dialog with the Knowledge Engineer

Figure 2-14. Parts of a rule based expert system.

The inference mechanism can explain to a system user, regardless of computer literacy or experience, the reasoning behind the decisions made. As process rules, orders of operation, or company policies are altered or changed in the knowledge base, the new guidelines can be immediately put into effect without any interpretation delay by company employees.

The Knowledge Base in an Expert System

As shown in Figure 2-15, the rules, facts, or heuristics that may be applied to a particular domain are stored in the knowledge base of the expert system. Not all rules will apply to every case that is tested, but the rules or facts for all of a specific domain are stored in the knowledge base. The term "domain" refers to a *specific* area of application such as welding or industrial ventilation design (Finn & Reinschmidt, 1987). Heuristics are rules of thumb that have been developed over time for decision-making.

The "domain expert" is a person who is recognized as having the most recognized knowledge of the particular domain. The domain expert may be considered a specialist

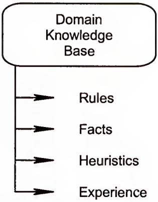


Figure 2-15. The contents of the knowledge base.

through advanced training and education (e.g., a doctor who specializes in kidney failure) or has acquired specialized knowledge or rules of thumb developed over time (e.g., a cab driver knowing the fastest routes across town).

Non-experts lack experience in the subject domain area. Depending upon the complexity of the domain topic (e.g., Tax Law), a person may take years to become an "expert" within his/her field. In many firms the domain expert is the person recognized as the most familiar with a particular topic. The process of building the rule base and capturing the domain expert's knowledge is explained in a later section of this chapter.

Techniques for the Development of Expert Systems

Several different techniques have evolved over time to be used in the creation of expert systems. These techniques have included the use of case-based expert systems, model based expert systems, artificial neural networks systems (ANNS), genetic algorithm based systems, and rule based systems (Li, 1996). Rule based expert system shells provide an appropriate methodology for implementing expert systems and workflow. Expert system shells can be thought of as empty domain knowledge bases designed for development. Typical business processes are based on rules (e.g., "a purchase order may be issued to only one vendor") (Appleton, 1995). The knowledge base of the domain can be developed by modeling the subject firm's workflow processes as part of the implementation of workflow. Don Rasmus (1997), a Senior Editor for PC AI magazine, observes that "workflow and expert systems share much of the same terminology in terms of representing processes about objects, constraints and rules" (p. 17). Rules also provide a natural mechanism for capturing expertise and have the flexibility for incremental growth, development and improvement which is important for prototyping the system and ensuring that it runs smoothly (Klahr & Waterman, 1986). As more users are put on line with the system, the system is further improved by incorporating their feedback and experience (Finn & Reinschmidt, 1987).

Process of Building the Knowledge Base

The information necessary for the proper establishment of a rule base for use in an expert system must fulfill two key requirements (Pigford & Baur, 1995). The first of these is the acquisition of knowledge, or knowledge elicitation, from the human experts interviewed as part of the modeling process. According to Mayer, Benjamin, Caraway and Painter (1995) using knowledge acquisition methods developed for the artificial intelligence community aids the development of the process models by providing both a process description and model. The second key requirement is the organization of the knowledge collected in order to make the knowledge base, or rule base, as effective as possible.

Two different approaches have been developed to capture the knowledge of the human expert in the development of an expert system rule base as shown in Figure 2-16 (Ignizio, 1991). The first method is the acquisition of information directly from the human domain expert. The second method of capturing human knowledge focuses on the development of rules by relying on the use of historical records. Usually this method is used to convert a previously developed database consisting of heuristics, customer preferences, or company background information into a set of production rules.

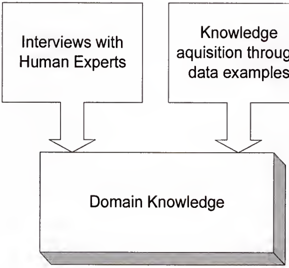

Interviews with Human Experts
Knowledge aquisition through data examples
Domain Knowledge

Figure 2-16. Approaches to gathering domain knowledge.

Knowledge Acquisition from Domain Experts

Several different methodologies have been developed over time for the process of knowledge elicitation or knowledge acquisition from the domain expert as no singular method has proven to be universally effective (De La Garza, Ibbs, & East, 1988; Hart, 1985; Liou, 1992). The most common methodology for knowledge acquisition from the domain expert utilizes a process of in-depth interviews conducted by the "knowledge engineer" the role assumed by this researcher. According to Yin (1994), this method of collecting information is one of the most important sources of case study information.

Three types of interview methods are commonly used to gather information from the domain experts: (a) structured interviews; (b) unstructured interviews; and (c) group interviews.

In structured interviews a list of pre-established questions may be asked of each respondent. The problem with this technique in knowledge elicitation is that the desired information may not "fit" as a response to one of the questions asked. The structured interview technique is more useful in situations where multiple visits to the domain expert are possible, but time is limited.

In unstructured interviewing, which provides greater breadth than the other interviewing methods, a specific list of detailed questions may not exist. Instead, the interview is typically open-ended in nature. From information elicited from the domain expert spontaneous questions can be asked that provide for better comprehension of the process or rules that may be invoked. It is not uncommon that the unstructured interview start off with some specific pointed questions to get the interview going and than becomes less structured to allow more specific or detailed information be gathered.

Because each firm visited as part of this research operates with different protocols, rules and organizational structure a combination of structured and unstructured interview techniques were used. Each interview started as a structured interview and then, depending upon the answers received, unstructured questions were used to follow-up. This provided for the best opportunity for sorting through process complexity in order to identify process controls, provide activity definitions and determine employee roles within the processes. A complete description of the types of questions asked is provided in Chapter 3.

The third type of interviewing is group interviews. An example of this is the focus groups commonly used in marketing research. The group interview technique was not used in this research because of the time constraints of the participants and the possibility that topics covered within the interviews often covered sensitive areas that may have provided potential embarrassment on the part of upper management over the fact that policies or processes being studied were not clear or were not being followed.

Benefits of an Expert System

A number of potential benefits from using expert system shells are provided to the constructor including improved productivity, ease in the development, and maintenance of the system (Carrico, Girard, & Jones, 1989). Other potential benefits to contractors utilizing expert systems to control their workflow are shown in Figure 2-17.

The ultimate effect of the benefits shown in Figure 2-17 is to reduce the overhead cost of the construction contractor by preventing mistakes. Policies and procedures are followed and applied in a consistent manner. Delays, caused by variation within the system, are eliminated. The shell has the ability to explain the reasoning behind the decision making thereby providing for a mechanism for training for new employees or disseminating information as decision making rules change. Davenport (1993) and others (e.g., Turban,1995) have suggested that expert systems are useful in controlling the workflow for a number of reasons which are summarized as:

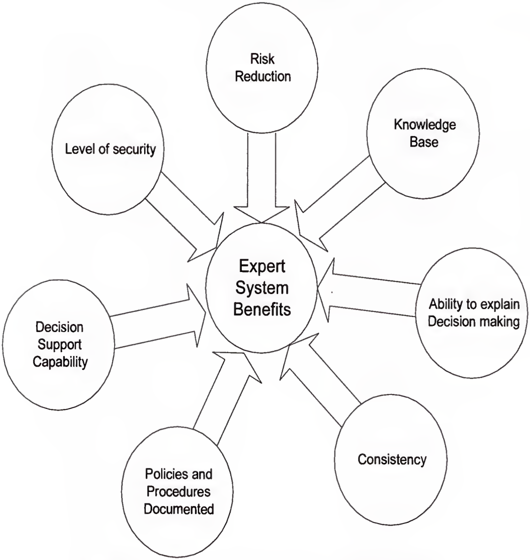


Figure 2-17. Summary of benefits of expert systems.

1. Risk reduction
2. Knowledge base
3. The Ability to explain
4. Decision support capabilities
5. Rapid prototyping of the system network
6. Ease of use by non experts

7. Cost
8. Ability to interface with outside database management systems (DBMS) like Lotus Notes®
9. Ability to interface with available workflow software packages

As guidelines, procedures, and practices are developed as part of the workflow process model, developed controls can be introduced into the expert system. Controls are necessary for management "to ensure that risk reducing procedures are followed and that the criteria for safety, budgets and schedule are met" (Hollnagel). Decision support can also be provided by the system for training of new employees on the company's policies and procedures with the use of hypertext or hyper media applications.

Concluding Remarks

Chapter 1, Introduction, provided some background regarding the issues leading to this research and the research objective. This chapter has provided the historical background of the area of information technology known as workflow. The confusion around what is meant by the term "workflow" was dispelled by examining the different components that are considered to be a part of workflow. The problem of management information overload due to massive amounts of raw, unfiltered data generated from construction operations was outlined in citations from the relevant literature. The concept of exactly what is workflow was clarified and explained in detail. The three different categories of workflow – ad-hoc, administrative, and production – were examined and examples of each type provided.

Three major subject areas were explored: workflow, process modeling, and expert systems. The association of workflow with business process reengineering and for use in the error prevention efforts of Total Quality Management were also explained. The use of business process modeling, why it is critical tool for workflow development and some of the modeling techniques developed were covered. A discussion of process modeling in the construction industry has been provided. Background information on expert systems including their history and development was provided along with examples of applications developed for the construction industry. A review of knowledge acquisition techniques, critical for the development of the rule base, has been furnished. Lastly a review of the benefits that an expert system controlled workflow would provide a contractor is provided.

Of the remaining dissertation, chapter 3, Methodology, will explain the research approach taken in developing this dissertation, including how the companies were identified for inclusion in the research. The methods by which the data collected was validated and an explanation of the types of process modeling questions asked of the domain experts at each company are also provided. Chapter 4, Analysis of the Data, details an analysis of the information found in the case studies described in the appendices. Included in each case study are the developed and validated process models of the existing processes that each company follows and the revised process model after the implementation of workflow. Chapter 5, Conclusions of the Study, presents the scholarly contributions and the "to-be" developed models produced by the researcher based upon the conclusions drawn from the interviews conducted. Chapter 6, provides suggestions for three areas of future research into workflow applications for construction.

CHAPTER 3
METHODOLOGY

This chapter discusses all of the steps taken during this research to identify, model, and document the reporting and document handling processes by which construction managers make certain decisions. The chapter begins with a brief overview of the methods used in developing this research and is followed by the rationale for data collection, a discussion of the data collection procedures, and sources. The method of data recording and validation of the data is detailed, and the steps for contractor selection and data analysis is addressed. Finally a discussion of the researcher's background, vital in any qualitative research project, is discussed.

Research Approach

The focus of the research has been on the processes of certain construction management decisions rather than the outcomes or products of those processes. Because the research crossed several scientific or academic disciplines (e.g., information systems technology, organizational behavior, business process reengineering, qualitative analysis, etc.), in order to properly research the problem, the project was broken down into a series of overlapping phases which are shown in Figure 3-1. Several research techniques were utilized with the central method consisting of a combination of structured and open-ended interviews with domain experts in General Contracting or Construction Management firms with more than 25 million dollars in annual volume.

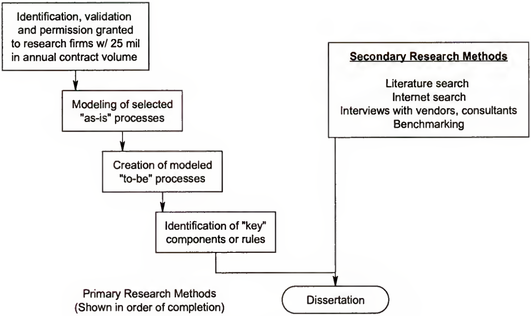

Identification, validation and permission granted to research firms w/ 25 mil in annual contract volume
Modeling of selected "as-is" processes
Creation of modeled "to-be" processes
Identification of "key" components or rules
Secondary Research Methods
Literature search
Internet search
Interviews with vendors, consultants
Benchmarking
Primary Research Methods (Shown in order of completion)
Dissertation

Figure 3-1. Research methods utilized.

This research has examined three different management processes common to construction firms: (a) labor reporting, (b) payment requests to the owner, (c) change order reporting. The ultimate outcome of this research is to assist construction managers and other researchers to develop a rule base for an expert system designed to control the workflow within a firm. By its very nature, the types of information necessary for the generation of an expert system rule base (i.e., the company rules, policies, process ownership and process heuristics) are qualitative not quantitative.

This study employs a multiple-case study research methodology as described by Eisenhardt (1989), Yin (1994), and Miles and Huberman (1994). This methodology focuses on developing a deep, richer, understanding of the dynamics present within the settings of the processes examined within each company. Furthermore, multiple-case sampling provides for additional confidence in the findings. Companies investigated as part of the research were selected on the basis of the replication strategy of meeting specific criteria to assist future researchers.

Interviews were conducted to learn how construction companies handle the activities involved with payroll, change orders, and processing requests for payment. The existing processes were decomposed and modeled through the use of standardized business planning and process techniques to create generic "as-is" activity models of how these processes are completed in the construction industry. As observed by Aoud et al. (1993) "process modeling simplifies the understanding of the construction process" (p. 385). The roles or actions of the actors in the processes were analyzed and described for future researchers. Then, new, generic "to-be" models of these processes were created with the intent of showing how the processes can be reengineered, automated and controlled by using workflow technology controlled by an expert system. These are provided in Chapter 5. This information provides for better understanding of expert system utilization and implementation of advanced information technology in smaller construction firms that do not have information system departments to handle computer problem troubleshooting.

Other methods of gathering data that were employed included historical and background literature search, and interviewing primary sources on workflow implementation such as information systems consultants and workflow vendors. Some secondary materials (e.g., information from professional associations, the Internet, etc.) were also utilized. Additionally, related case studies found in the literature search and development efforts of knowledge-based systems applied to business problems were examined.

Given the results of the discussion in the literature review, it appears that, as an industry, there is a lack of information available on management processes within construction firms to develop a working rule base for an expert system to control the workflow process within a construction firm. Much of the construction industry's information flow is too much raw data and not the information necessary for decision making.

Rationale for Data Collection

The production rules, or heuristics, that form the knowledge bases of the expert system are often not easily identified or explained. In the more complex, inter functional processes that are common to business operations, process ownership and process controls are often ambiguous and undefined (Melan, 1993). Strict quantitative survey research methods do not provide any mechanism by which to establish process ownership, map processes, customs of employees or information flows. Such a detailed analysis is only possible if one can obtain direct access to domain experts and process users by conducting interviews. The process mapping required of any type of workflow implementation program requires interviewing the participants involved in the process. Gummesson (1991) asserts that "among the methods available to the traditional research, *qualitative* (informal) interviews and *observation* provide the best opportunity for the study of processes" (italics in the original) (p. 30). Furthermore, as Agarwal and Tanniru (1990) have concluded, the use of interview technique provides the advantages of "immediate feedback" and "issue clarification" for the interviewer which provides for a more accurate process model.

The use of qualitative analysis methods is commonly accepted in the social sciences (e.g., Sociology, Anthropology, Education, etc.) for use in data collection and analysis. The techniques utilized in qualitative analysis are the same as those used by a business consultant, a knowledge engineer, or a systems analyst to gather data about a particular process. Generally speaking, qualitative analysis can be broken down in to four categories of procedures or data collection strategies summarized in Table 3-1 (Tashakkori & Teddlie, 1998):

Table 3-1. Categories of data collection strategies.

Using extensive field interviews to ask people about information or their experiences.
Observing what people do and recording or making inferences about their actions.
Interviewing individuals about their relationships with others, their customs, or the culture they live in or work in.
Using archival data collected or documented by others.

The volume of data collected must be reduced and interpreted with the goal of a consolidated picture of the process developed (Miles & Huberman, 1994; Patton, 1990; Yin, 1994). The process of data collection for this research and the method of contractor selection are discussed in a later section of this chapter.

Data Collection Procedures and Data Sources

The study proceeded in two stages of data gathering as shown in Figure 3-2. In the first stage, interviews were conducted with high level managers (e.g., Vice Presidents, Operations Managers) and others in the construction firms that agreed to be

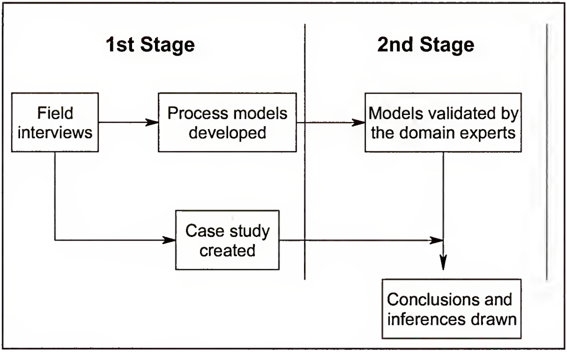


Figure 3-2. Stages of data collection in this research.

part of the research project. These persons were typically recognized as the "domain expert" within the company unless another person was specifically identified by the contact individual. Based on the results of these interviews, the models were developed and cross checked for validation. The second stage, the validation process of the information gathered, is discussed as a later part of this chapter.

The type of interview format depended upon the person being interviewed. The initial identified domain expert within the firm was interviewed in a semi-structured, open-ended format whereby they were asked to "talk-through" the process in imagining what they would do or talking through a specific case (Hart, 1986). This method serves two purposes. First, it provides a mechanism to put the domain expert at ease in talking to the researcher about a familiar topic. Secondly, as noted by Agarwal and Tanniru

(1990), it provides the researcher a broad familiarity with the characteristics and decision-making of the company under study, which is useful in the early stages of knowledge acquisition. A third benefit provided to the researcher is that cross-case comparability is easier to build instead of attempting to reduce volumes of data collected as part of the interview process (Miles & Huberman, 1994).

Each interview began with a general discussion of the research that was being conducted, what information was being collected, and who within the firm may be interviewed and the confidentiality of all information shared with the researcher. The initial questions dealt with the company itself and were designed to put the domain expert at ease by discussing something he or she was comfortable speaking about and intimately familiar with.

From the discussion of the company, the course of the interview would focus on the three areas of reporting processes under examination of payroll recording, handling of change orders, and processing requests for payment or information by the owner. The types of questions asked can be generally broken down into three overlapping areas of process, ownership, and culture. Examples of the three types of questions asked are provided in Table 3-2. The full list of questions, from the structured portion of the interviews, is provided in Appendix B. These questions are designed to be somewhat open-ended in order for the domain expert to produce a more carefully developed response as well as providing information to the researcher as to how processes are conducted within the firm. Not all questions were asked in all interviews as the questions were designed to build upon the responses to earlier questions.

Table 3-2. Process modeling questions.

Process Questions	How is the information collected?
	Where is the data collected?
	Who is responsible for collecting it?
	Who handles the information?
	What verification procedures are involved?
	Who else may get a copy of the transformed data?
	How do you know when the process is completed?
	How often is the data handled?
	What are the transformation steps from data to information?
	What do you do with the collected information?
Ownership Questions	Who "owns" the process
	Who is responsible for its completion?
	How do your internal "customers" impact the process?
	Does the owner of the company review the data or the transformed information?
Culture Questions	How long has the process been performed in this manner?
	Is the data collected manually or electronically? Why?
	Is there a written company manual about the process?
	Is the company manual followed?

Process questions are designed to identify activities and data collected as part of the process itself. Process questions can be thought of as the lowest level of questions or the micro level of information details of the process. The decision making rules of the process are determined as part of the process questions. Examples of decision making rules are how labor is to be accounted for on the weekly time reporting payroll sheet or whom the person responsible for typing up a request for payment in the office will be.

Ownership questions examine the areas of process "ownership" and process completion responsibility. Typically, "ownership" and responsibility may be assigned to two different persons within the construction firm. However, many firms may not recognize the concept of "ownership" of a process, instead only identifying responsibility for that process being completed.

Culture questions occur at the macro level probe the cultural setting of the firm (e.g., the ownership structure, type of clientele, type of craft worker hired, union or nonunion, etc.). Culture influences processes in more subtle ways than decision making rules, but must be understood if implementation of any workflow system would be acceptable. The importance of company culture is further discussed in the analysis section of this research.

Structured, or focused, interviews were conducted with lower level participants in the processes being modeled. The major purpose of these interviews was to corroborate or validate certain facts provided by the domain expert.

Additionally, a survey form was developed to collect information about the types and level of computer usage among employees of the firm. A copy of the computer usage survey is provided in Appendix C. Questions regarding the use of advanced specialized software programs developed for use in the construction industry (e.g., estimating, scheduling, or document management software) were asked. Questions about each firm's level of networked employees, if any, were asked. The domain experts at each firm were asked about their firm's use of expert systems, databases, and groupware applications that may be used. Finally, questions were asked about the use of spreadsheets, a method found by Nardi and Miller (1991) to be an excellent indicator of the level of computer supported cooperative work among employees as they develop macros, templates, etc.

Data Recording Procedures

Contractors were visited in their offices, and all interviews were recorded by the researcher after permission was granted by each interviewee. All interviews were held in a one-on-one meeting with the researcher and the researcher's role acknowledged. Great effort was taken so as not to lead the participants unintentionally. In every case the confidentiality of the interviews and information gathered was stressed with the promise that proprietary information shared with the researcher would be withheld.

Each company interview followed the same agenda (found in Appendix A) and set of research questions asked (found in Appendix B). The objective set forth was to increase the reliability of the information collected by following the same case study protocol with each firm, but by a later investigator. By following the same protocols for each case study, the errors and biases can be minimized and the goal of reliability achieved (Yin, 1994).

At the time of the interviews with the domain experts, a preliminary "sketched" model of the process being discussed, or running commentary about observations or questions to follow-up, was made by the researcher in a set of informal field notes. Eisenhardt asserts that keeping such field notes provides several major advantages to the researcher in terms of allowing for more flexible data collection in order to further probe particular themes or hunches which may emerge about relationships (Eisenhardt, 1989).

Validation of the Process Models

Once a raw model and description of the process has been developed, it must be refined to produce a structured, knowledge-rich view of the process through validation of the information gathered (Mayer, Benjamin, Caraway, & Painter, 1995). Validity of the process models was tested and their integrity improved by a combination of what Patton (1990) calls "methodological triangulation" including the use of document analysis, interviews and cross-checking of findings. The limitations of replicating the study are discussed in a later section of this chapter.

The internal validity of the process information and developed models was checked by each company domain expert. After completion of the "as-is" process models by the researcher, copies were mailed to each of the domain experts. Telephone conferences were held with each of the experts to verify the information and models were correct as developed by the researcher. Changes to the models after the initial verification were rechecked by the domain experts at each company to ensure accuracy.

At each company investigated, the actual forms and applicable pages from the company policy or procedures manual were requested for analysis by the researcher. However, it should be noted that at some firms, the policy and procedures manuals were under revision, were not current, or did not exist.

The initial request for interviews and data modeling was made to a senior level executive in each firm. Once inside a company, however, every attempt was made to interview the actual participants (e.g., project managers, project clerks, superintendents, etc.) in the processes being studied. Interviewing the process participants increases the validity of the process models by triangulation of source informants. The information solicited from senior executives, unless they were identified as the "owner" of a process or were otherwise involved in the process, was primarily background information on the company being examined. The reason for this was to focus on the development of accurate process models to produce a clear understanding of the operational details of each process that would not be tainted by inaccurate information, or confusion about the actual process by members of upper management.

In any qualitative research project a goal of the researcher is to immerse himself/herself in the culture in order to develop a better understanding of the subject under study. So the question of why not a longer term anthropological approach was taken to the case studies must be addressed. The business processes under study are inherently very quick and short. Because of the nature of the examination process, and the time constraints faced by the subjects under study, a longer term approach or multiple visit approach to each firm in the study was not feasible.

The Interaction Process and Parameters for Data Collection

The importance of the interaction between the expert system knowledge engineer, the role borne by this researcher, and the human expert(s) of the particular domain of knowledge is of critical importance to the proper development of the rule base and in any qualitative research process. The interview technique used in this research required that the researcher visit contractors and construction managers within their own offices, which provided several advantages over conducting meetings in a "neutral" location such as a restaurant or conference site which may provide potential distractions. The most immediate advantage provided was that any records or support personnel involved in the process were readily available for clarification or reference if any questions arose during the interview with the company domain or process experts. Brulé and Blount (1989) suggest that it is crucial for interviews to be conducted in contextual surroundings familiar to the interviewee so that the "cuing" potential, or the remembrance of different methods of approaching a task, of the domain expert is optimized.

A secondary advantage provided to the researcher was the opportunity to gather several different views from project management or support personnel quickly. Typically, this provided reinforcement of information garnered from the preliminary interviews, but in some instances employees were able to provide comparisons between the company processes under study and how they differed from similar processes run at a former employer or from earlier process systems used by the company. What is more important, for the development of better models, is that the environment or context that influences decision-making within the firm are captured in on-site interviews. Agarwal and Tanniru (1990), observe that while incomplete information is not a serious problem for experienced decision makers, particularly in decision support systems, the expert system is "intended for novice users who may be unable to assess the relevance of information excluded from the system adequately" (p. 127).

Information about technological and organizational changes over time could not be collected systematically, because the knowledge of the respondents varied widely with their tenure at the company. Given the difficulties in collecting historical data, it was determined that further analysis had to focus on studying the process of information management and the type of information that is used, which often differs at the various levels within each firm, rather than the changes of information over time. To better understand how people use the data collected, what they do with it, and how they handle it required that the people involved in the processes under study be interviewed separately and independently from their supervisors. As with all other interviews, these were conducted in confidence to protect the observations of the interviewee and the firm he or she represented. Wherever individual perceptions differed, questions were asked to further probe those differences. The differences were compared with other employees involved in the process, if any, until the reasons for any differences (e.g., personal preference) was understood by the researcher.

Semi-structured interviews were conducted with the contractor's employees that were identified by the contact person as the domain expert within the firm, typically a senior project manager or vice president of operations although the actual title varied with each firm. In several cases, the president of the firm was interviewed first as the domain expert.

At each contractor visited, in addition to interview data, contextual data were gathered in the form of labor reporting forms, project management checklists, policies and procedures manuals, change order logs, and request for payment logs, which are used to substantiate and validate the researcher's understanding of each company's process and cross-validate the interview data obtained. Whenever possible, copies of the contextual data was taken the researcher for further study and analysis to assist in the development of the process models.

The Contractor Selection Process

The utilization of purposeful criterion sampling provides for greater quality assurance in the qualitative analysis and the development of the process models. However, the construction industry is highly fragmented in terms of company size and type of work performed. In view of this situation, the research employed the comparable case selection sampling method as described by LeCompte and Preissle (1993), whereby the researcher establishes in advance the criteria or relevant characteristics that the individuals, groups or companies must have to be included in the research study.

Contractors, or construction managers, in order to be considered for inclusion in this research, were required to have met two criteria. The first criterion factor necessary for inclusion in the pool of study candidates was that the contractor or construction management firm had a sustained annual volume of at least 25 million dollars in work. Firms doing less than 25 million in volume were not included because their annual volume is such that they have a flatter managerial structure and do not have the annual volume necessary to support a more powerful information technology infrastructure.

The second criterion for selection of contractors was the type of work they performed. For inclusion into the research database, potential contractors had to list their primary specialty as either “general” building contractors or construction managers. Contractors that were primarily or unique to “sub” contractor classifications (e.g., an electrical contractor or a concrete contractor) were excluded from the survey database. Subcontracting firms were not included in this survey for two reasons. First, the pool of subcontracting firms that have a volume more than 25 million dollars is considerably more limited than General Contracting firms. Secondly, the process reporting requirements for these firms are considerably simpler than for General Contracting firms that must deal with a variety of different clients.

Background information used for the purpose of developing a database of contractors came from secondary sources such as industry trade magazines like

Engineering News Record and industry associations like the Associated General Contractors, Inc. As part of their listing within the research database, contractors were identified by the type of work they performed. For example, a contractor may be listed as "Duvel Construction (B/CM/HZ)" which indicated that the contractor handled hazardous materials removal or installation in addition to being a building contractor and construction manager.

Each contractor in the database was then contacted by telephone, whenever possible, to provide a correct fax phone number. The contractors were broken down by state to facilitate the faxing of letters of invitation for this researcher to visit their offices and to develop a model of their management processes being studied as part of this research. A sample letter is shown in Appendix D. A convenient "fax back" form was provided for each contractor to fax back to this researcher a confirmation of whether the contractor wished to participate in the research or not participate. A copy of the "fax back" confirmation form is in Appendix D.

Contractors that were not able to be contacted by telephone, due to closure of offices, a merger with a larger firm, change in mailing location or for other reasons, were dropped from the database and consideration in the study. Another problem encountered was the difficulty in identifying the appropriate respondent with the construction firm's headquarters. The letter of invitation was targeted at whoever was listed in secondary sources of information, typically the president of a firm, but in some cases the "branch manager," "marketing director," or some other official in the firm. After a person was identified, a telephone call to the company headquarters was made to confirm the information and to establish whether that person would be an appropriate respondent. A difficulty arose in identifying a senior corporate officer who is familiar with the processes to be examined as well as the issues of information technology within the firm. The level of company president may have been too high in the corporate hierarchy, particularly with larger firms, to secure a useful response rate. However, lower managerial ranks and administrative personnel are very difficult to identify, without more direct access to the company.

A total of 221 contractors from nine states were eventually included in the research database. These firms were identified as general contracting or construction management firms that met the criteria discussed earlier. This list of 221 entries was narrowed to a list of 88 contractors by eliminating duplicate regional office listings, unverifiable telephone, address or fax numbers, and unidentifiable company officers. Letters to these 88 firms in five states were faxed out to the identified company officer with ten firms responding positively that they would accept a visit by the researcher and participate in this research. Eight contractors were selected for interview sessions and their processes modeled with one site serving as a pilot study to evaluate the research design and field procedures. Each case study has been set up as an individual chapter. The result of each case study and discussion of these sessions are found in Appendices F through M.

Approach to Sample Size and Data Analysis

A significant difference between qualitative and quantitative approaches to research is the question of required sample size. Case study research does not require a large number of cases to be correct, and there are no specific rules for sample size in qualitative inquiry (Patton, 1990, p. 184). Rather, a tradeoff between the depth of analysis and the breadth of cases to be examined exists. The data being reported should be collected and analyzed until it is apparent that no new information is being collected (Seidman, 1998). Some researchers have suggested an ideal of a minimum of four cases. Eisenhardt (1989) has stated "a number between four and ten cases usually works well" (p. 545). Others (e.g., Patton, 1990; Creswell, 1994; Yin, 1994; Seidman, 1998) do not recommend a particular number; instead, they suggest that the issue is subject to the review and judgement of the researchers involved, as well as the practical limitations of time, money, and other resources. The ideal situation is when theoretical saturation has been reached or incremental learning is minimal because observed patterns are being repeated (Eisenhardt, 1989). This researcher has attempted to provide more of an in-depth analysis of the individual company processes examined, by the creation of diagrammatic models, rather than examining a large number of cases. The process models are not created separately from the analysis of the interview data, nor merely built from the discussion of the participants, but as an integral part of the analysis.

The Data Analysis Process

Exploratory development analysis, such as this research, requires that a number of open-ended questions be asked since there is no clear hypothesis regarding the answers. Raw data comes in multiple forms from a variety of sources including field notes by the researcher, historical documents, and open-ended interviews with the domain experts or others involved in the process. The typical method of display for pure qualitative research is pages of unreduced text provided by the researcher (Miles & Huberman, 1994). Because of the type of information being examined and the desired outcome of this research effort, it was necessary to apply some method of data reduction.

One commonly accepted method of data analysis and data reduction in qualitative research is the assignment of labels or tags, called codes, to the information compiled (Swift, 1996; Miles & Huberman, 1994). This research has employed the use of *descriptive* codes to identify or interpret the actions and rules of the actors involved in the three processes as described by the domain expert. One case study transcript that included descriptions of all three processes was selected for the creation of initial coding concepts for each process. The purpose of doing so was to create imprecise general categories of actions each actor might take (e.g., collect, review, verify, record, etc.) by locating instances of the action described. Data matrices were used to help identify the

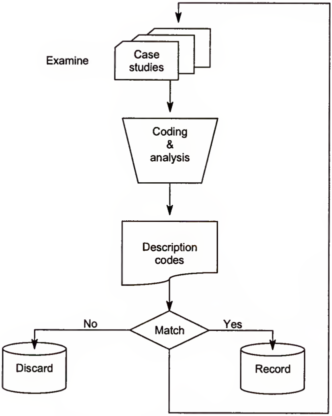


Figure 3-3. Data analysis cycle.

common or similar attributes for each code across the different interviews. Those attributes not supported by the data were revised or discarded. Other additional attributes of actions, not found in the pilot case study, but found or repeated in later case studies were added. The process of data examination continued in an iterative manner, as shown in Figure 3-3, until all of the transcripts had been analyzed for all three processes. Each transcript was then analyzed for rules that apply to the actions found. As an example, for the action "get price information" the rules that may apply, which are judgement or verification procedures to the project manager for that particular action, were found to be 1) perform scope analysis; 2) do I need and estimator; 3) how will the change order affect the schedule?

Reporting the Findings

The three internal, interfunctional support processes under study (labor reporting, payment requests to the owner and change order reporting) are broken down into object based process flow models that are discussed as a part of each case study. The models graphically display the specific series of tasks that must be completed in a particular order to complete each process. The development of graphical process models provides many benefits, which are summarized in Figure 3-4, and are critical in any reengineering effort for the implementation of workflow.

Each case study presented represents the refined, corroborated, cumulative results of the research interviews with the domain expert and "actors" that impact the process. All of the case studies follow the same general outline provided in Appendix E. A brief summary of the companies profiled as a part of this research is shown in Table 3-3. The aliases given to the construction companies profiled and the domain experts at each

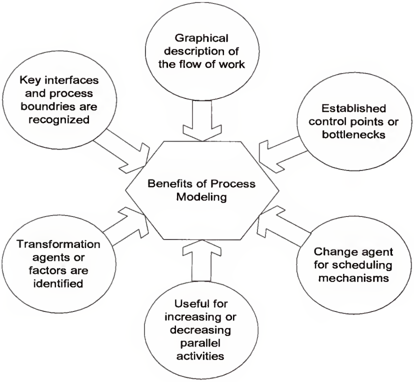

Graphical description of the flow of work
Key interfaces and process boundries are recognized
Established control points or bottlenecks
Benefits of Process Modeling
Transformation agents or factors are identified
Change agent for scheduling mechanisms
Useful for increasing or decreasing parallel activities

Figure 3-4. Summary of process modeling benefits for reengineering and workflow implementation.

company interviewed, as part of this research, are designed to protect their identity and are used to identify the case companies throughout this research. The case studies have been designed so that each may be studied independently of each other. The eight case studies presented as Appendices F through M of this dissertation.

The models created as part of this research were object based models developed to provide a descriptive representation of the three processes under examination. Labor reporting is what Soares and Anderson (1997) in their paper "Modeling Process Management in Construction" would classify as a "project-level business process" (p. 46) since it supports the administrative details of project operations. The request

Table 3-3. Contractor case study profiles.

Case Contractor #1: a.k.a. *"EDO Construction Company"* - General Contractor Annual contract volume ~ $100 million Processes examined and modeled: Labor, Change Orders, Request for Payment
Case Contractor #2: a.k.a. *"ABC Construction Company"* - General Contractor Annual contract volume ~ $200 million Processes examined and modeled: Labor, Change Orders, Request for Payment
Case Contractor #4: a.k.a. *"Q and Q Construction Company"* - General Contractor Annual contract volume ~ $40 million Processes examined and modeled: Change Orders, Request for Payment
Case Contractor #3: a.k.a. *"XYZ Building Company"* - General Contractor (Foreign ownership and international work) Annual contract volume ~ $250 million Processes examined and modeled: Labor, Change Orders, Request for Payment
Case Contractor #5: a.k.a. *"BBB Construction Corp."* - General Contractor Annual contract volume ~ $40 million Processes examined and modeled: Change Orders, Request for Payment
Case Contractor #6: a.k.a. *"FLD Construction Company"* - General Contractor Annual contract volume ~ $200 million Processes examined and modeled: Labor, Change Orders, Request for Payment
Case Contractor #7: a.k.a. *"CDL Constructors, Inc."* - General Contractor Annual contract volume ~ $200 million Processes examined and modeled: Labor, Change Orders, Request for Payment
Case Contractor #8: a.k.a. *"PQR Construction Company"* - General Contractor Annual contract volume ~ $100 million Processes examined and modeled: Labor, Change Orders, Request for Payment

for payment process and change order request process are what Soares and Anderson (1997) would identify as "company-level business process [that] support ongoing organizational operations to sustain [the] business" (p. 46).

At each company studied, the process models of the three existing, or “as-is,” processes were developed. Each model graphically shows the “actors” (e.g., payroll clerk, project manager, computer, etc.) involved in the process and lists the actions (e.g., review change order, approve pay request, etc.) the actors apply to the process. The developed models are presented in Appendices F - M respectively. Note that two of the companies interviewed, Q and Q Construction and BBB Construction Corporation, do not have any of their own field workers, nor are they responsible for keeping track of the field employees’ time. For those two particular firms, all non-supervisory craft workers were either Union tradespeople or employees of subcontractors, and consequently they do not have process models developed for labor reporting.

From the different process models developed for each of the companies in the study, a synthesized process model for each process has been developed. The synthesized process model can be viewed as a theoretical “to-be” model of the reengineered workflow process with the expert system controlled workflow mechanism in place. The “to-be” models are presented in Appendix N in comparison views of the “as-is” models. The analysis of the information collected is presented in Chapter 4.

Limitations of the Study

Qualitative research analysis is sometimes accused of not standing up to the scientific rigor of more quantitative methods because the data collected is more contextual and descriptive in nature, or the data is gathered in such volumes that the data can be interpreted in multiple ways. Another problem is that some knowledge may still be missing from the data flow diagrams or the analysis of the interviews. This knowledge may be in the form of common knowledge or common sense assumptions that the domain expert assumes the researcher already has made and consequently leaves it out of the interview session.

This difficulty of assumed understanding or multiple interpretation can only be overcome by data verification of the information gathered by triangulation of the data. Typically the problems of assumed common knowledge are reduced or eliminated through the use of multiple interviewers and the cross comparison of notes from the interviews taken. For the lone researcher these are inherent problems that can only be overcome by the use of multiple interviews with the domain expert or others involved in the process and increased examination of written data in the form of memoranda, policies manuals, and written directives.

A second question arises from the development of the models themselves: how do we know if the model is complete? As noted in Chapter 2, there is significant debate on the degree of examination that the process model needs to obtain. Because this research was promulgated with the idea of being able to develop a hypothetical rule base for future researchers, a greater level of analysis has been approached than would normally be required for merely de-constructing the process. Furthermore, the completed models were refined in an cyclical manner of development, comparison and refinement with the domain expert at the companies interviewed until each model could be stated to be a correct validation of the process under study.

The third limitation or difficulty encountered as part of this research is the domain experts themselves. The domain experts are what Marshall and Rossman (1989) would label as "elites" within the companies examined because the domain experts are "the influential, the prominent, and the well-informed people in an organization" (p. 94).

These people are typically very busy and difficult to identify from outside the organization. As noted by Marshall and Rossman (1989), the elites, or domain experts, "in general, resent the restrictions placed on them by narrow stereotypical questions" (p. 94). These people require special handling, and there is a danger that one is told "what you want to hear" and not "how it's actually done" because of recording procedures, lack of formal interview training on the part of the interviewer, or other unforseen problems.

Qualifications of the Researcher

Because qualitative research is interpretive in nature, the background, experiences, and training of the researcher are explicitly included in the research analysis (Creswell, 1994). Moreover, the development of the rule base and process modeling requires a certain amount of knowledge of the domain under consideration by the knowledge engineer or person developing the process model in order to understand the types of questions that must be asked and the answers provided that have meaning (Forsythe & Buchanan, 1989; Pedersen, 1989). Therefore, it is important to note that the researcher has been involved in construction management in a number of different roles, including project management, in the area of commercial and industrial construction for roughly eighteen years. A complete resume of the researcher is provided in Appendix F.

In each interview situation, the primary contact person for each company was made aware of the researcher's experience. The purpose of this was to allow the domain experts to become more comfortable and feel at ease that they were speaking to a colleague or someone with some knowledge of their business and understanding of the concepts and jargon used. However, this raises the possibility, which cannot be overlooked, that the researcher can miss something because the person being interviewed may skip over some issue by making the assumption that the interviewer is already familiar with the particular issue or decision step. In any knowledge acquisition situation, this is a possibility, but the dilemma can be minimized by the use of structured interviewing and repeated, but subtlety changed questions.

Chapter Summary

This chapter detailed the methods by which the process models were created and the data collected through extensive interviews and reference to company documentation. The chapter established how the critical question of case study and process model validation was applied in this research. The criteria for contractor selection to be a participant in the study was presented, and the rationale for number of case studies developed provided. The method of development of the process models was explained. The limitations of the study were discussed. The company profiles, the case studies, and the analysis of the process models are presented in Appendices F through M. The comparison of the "as-is" and "to-be" models can be found in Appendix N.

Chapter 1 provides the introduction to the study and why this research is needed. A comprehensive review of the literature covering workflow, process modeling and expert systems is found Chapter 2. The analysis of the data gathered from the companies interviewed is provided in Chapter 4. The discussion of the scholarly contributions of the research are presented in Chapter 5. Areas of research beyond the extent of this dissertation are presented in Chapter 6.

CHAPTER 4
ANALYSIS OF THE DATA

This chapter presents the analysis of the information found as part of the interviews conducted with identified domain experts at eight construction companies that agreed to be part of this research. The processes of labor reporting, request for payment to the owner and change order requests were examined in addition to the level of computer usage or sophistication at each company. In structured interviews, open-ended questions regarding how each company conducted these processes were asked of the domain experts and others involved in the processes under study. From the answers provided during these interviews, diagrammatic models of the existing, or "as-is," processes were created and validated with the domain experts. These models are presented as part of the case studies of each firm provided in Appendices E through M respectively. This chapter explains the analysis of interview information gathered.

This chapter begins with a discussion of the unit of analysis used for examining the text of the transcripts from the meetings with the domain experts at the companies interviewed. Next an examination of the data collected about the types of computer programs and networking facilities of each firm is provided. Background information of this type offers the researcher knowledge regarding the use level of information technologies within the firms included in the study. Following the discussion of the computer sophistication of the firms examined, the content analysis of the text of the interviews about the three processes examined as part of this research is summarized and reviewed. Proposed generic "to-be" process models of expert system regulated workflow based on the analysis of the decision rules and actions determined to control the process is provided for each of the processes examined.

Unit of Analysis

Case study research, even exploratory/descriptive research such as this study, needs some unit of analysis to provide a focus to the study. This research uses an embedded, multi-case design. The primary units of analysis have been the three processes of labor reporting, request for payment, and change order request. These processes were chosen as they are the most common support processes in the management of a construction firm.

The analysis of qualitative data requires that the researcher work inductively looking for emergent *patterns* or *themes* in the data (Patton, 1990). This study utilizes cross case analysis, which provides two major benefits to future researchers (Miles & Huberman, 1994). First, it strengthens the generalizability of the findings, which is crucial in developing theory. Second, it increases the understanding and explanation of the processes and the actions people take within each process.

Two analytic techniques have been employed to interpret the information collected as part of the interviews with domain experts and others involved in the processes under study. The first method has been to create a data display, or process model, for each of the processes under study at each firm participating in this research. The process models provide several benefits including the ability to graphically show the interaction between actors within each process, a means of communicating the processes to others, and as a basis of analysis for future work (Huckvale & Ould, 1994).

A graphical model provides researchers, the domain experts, and company managers with an easier to understand overview of each process without having to resort to the use of a computer modeling language. The models of the existing processes at each company are presented as part of the individual case studies found in Appendices F through M respectively.

The second technique applied to analyze this research is the use of descriptive codes to develop pattern matching. This technique, developed for qualitative analysis, uses codes to identify the descriptions of activities and the decision rules of the persons involved in the processes under study. The descriptions and decision rules have been amassed from structured open-ended interviews with domain experts and process participants at the companies examined. The process by which this analysis was completed and verified is discussed in Chapter Three of this dissertation.

Examination of the Level of Computer Use

A major factor in the acceptance of any type of information technology, both hardware and software, is the current level of use by employees of information technology within the firm. Questions regarding the use of specific types of software programs and who within the firm would use those programs were asked of each company. A copy of the computer usage survey form is provided in Appendix C. Table 4-1 shows the comparison between companies in the research base, based on contract volume, and the information technology or software examined.

Table 4-1. Summary table showing type of software used classified by company size.

Firm Volume in Mill. $	Use Spreadsheets	Estimating software	e-mail or Groupware applications	Networked	Expert Systems	Databases	Project Mgmt. Software	Document Mgmt. Software
200 +	ABC	ABC	ABC	ABC		ABC		ABC[1]
	XYZ	XYZ		XYZ		XYZ	XYZ[1]	
	CDL		CDL			CDL		
100 +	PQR			PQR		PQR	PQR	
	FLD	FLD		FLD		FLD	FLD	FLD
	EDO					EDO		
25 Mil +	Q&Q	Q&Q	Q&Q	Q&Q		Q&Q	Q&Q	
	BBB		BBB	BBB		BBB	BBB	BBB

[1] Have developed their own

Included in the usage survey were questions regarding estimating software, groupware applications, networking, databases, project management software and document management software. Groupware applications are software programs designed to enable workers to collaborate asynchronously with each other. The use of project management software programs, particularly if they are widely used throughout a firm, indicates a higher level of computer software knowledge and acceptance because of the greater complexity of these programs relative to more commonly used programs like word processing. Document management software is a fundamental part of any workflow system. The use of this type of software indicates a familiarity and acceptance on the part of management personnel of a potential workflow application.

Table 4-2 provides the summary of responses regarding the computer and software usage at each of the firms contacted. A commentary as to the type of question and why it was asked is provided for each response after the table. All firms in the research were found to have some minimal level of computer sophistication, but it varied widely between firms. Within one firm, EDO Construction, computer and software usage dramatically varies from level of position within the firm (e.g., Project Managers and Upper Managers) and between employees at the same level (e.g, one Project Manager may use his computer with a personal hand held computer and another would never log on the system, but have his assistant do it for him). Examination of Table 4-1 shows that there was no apparent correlation for purposes of *this* study that could be drawn between size of firm and level of software sophistication applications.

Table 4-2. Summary of responses regarding computer usage within companies surveyed.

General Question	Yes	No
1. Does the company use project management software (e.g., P3, MS Project, SureTrack)	7	1
2. Does the company use some type of document management (e.g. Expedition, Wellcom Open Plan)?	3	5
3. Does the firm use spreadsheets for projects (e.g., labor forecasting, cost control)?	6	2
4. Does the firm use spreadsheets for estimating purposes?	8	0
5. Does the firm use some type of "specialized" estimating software package (e.g., Timberline, MC^2, WinEst)?	4	4
6. Does the company use some type of "groupware" application (ex., Lotus Notes, e-mail, electronic white boards, video conferencing)?	4	4
7. Does the firm use any rule-based expert system programs or shells for decision making or support?	0	8
8. Does the company use any databases?	8	0
9. Does the firm use a computer network in the home office?	7	1
10. Does the field staff (superintendents, inspectors, etc.) use laptops for transmitting information to the office?	5	3
11. Are you satisfied with the level of training for computer applications in your firm?	5	3

Commentary on Table 4-2 Responses:

Question 1. As can be seen in Table 4-2, the majority of the companies surveyed are using advanced or specialized industry software programs. The majority of the respondents answering yes to this question further indicated that their superintendents also made use of the scheduling program. Use of sophisticated, specialized software programs provides a basis for the introduction of workflow programs.

Question 2. Document management systems provide a means of tracking document submittals, meeting minutes, and letters of transmittal. Many of the currently developed commercially available document management software programs also provide a means of communicating this information either through the use of e-mail or a replication database scheme like Lotus Notes®. Companies that are already using a sophisticated method of internal document control and retrieval are more likely to embrace the concept of workflow automation since they have used a introductory form of it in their own document management software.

Question 3. The use of spreadsheets for project tracking indicates that employees of the firm are accustomed to cooperative work in problem solving of computer applications and learning. Nardi & Miller (1991) found that spreadsheet use and development is an important tool in learning to apply computer supported cooperative work. Additional questions about "who used the spreadsheets" and "was training provided" were also asked of companies responding "yes" to this question.

Question 4. This question follows up on question three. Estimating brings in another dimension of employees that may not necessarily be directly involved in project control. All firms in the study were found to use spreadsheets for either project control (question 3) or for estimating (question 4). However, level of use within individual firms varied. One firm had some Project Managers that do not use any form of spreadsheet. Instead they preferred to use columnar pads. Another firm discussed how several different spreadsheet programs were in use.

Question 5. This question is designed to learn more about the level of computer sophistication among the employees of the firm involved in construction operations. Firms that may use specialized software programs for estimating, scheduling or accounting, for example, may restrict the use of these programs to estimating, scheduling and the accounting departments respectively, which has a tendency to create a smaller pool of more deeply trained or software sophisticated employees.

Question 6. Experience with groupware applications of any kind, but particularly e-mail, eases the transition of workflow into the firm. Conflicting attitudes about groupware applications were noted. Four companies responded positively that they were at least using e-mail for intra-company correspondence with one firm reporting that it had been using electronic white boards. However, one firm, EDO Construction, indicated that they were not likely to invest in any type of groupware application.

Question 7. The role of rule based expert systems for providing decision support is a critical one. However, currently none of the firms contacted as part of this research were using any type of rule based expert system. This is not entirely encouraging as expert system programs have been developed for specific construction industry applications (see Chapter 2), but given the overall level of computer use in the industry, this is not surprising based on the small scale of this research program.

Question 8. All companies indicated that databases are used in some fashion or another within their operations. This is important because the rule base in an expert system shell is a form of a database. Furthermore, much of a company's historical data and process information such as contractual data is typically stored in a database which must be accessed by the workflow system for it to operate properly.

Question 9. Workflow requires the use of a computer network for information or data to be moved from person to person within the process. While seven firms indicated that some form of network is in place, the level of network connectivity among employees varied. Some firms reported that all of their employees were on the network. Other companies maintained network "pockets" where only people of a certain position (e.g., Project Manager) had network access.

Question 10. Field staff, regardless of their title (e.g., Superintendent, Office Engineer), must be able to input information directly into the workflow system. Most companies surveyed provide their field staffs the ability to do this. Of the companies that currently do not one, EDO, has expressed an interest in doing this.

Question 11. Support for training is important for employees to learn how to use the workflow management software to its fullest potential. This question went directly to the domain experts of each company to determine their opinion regarding training within their firm. Their opinion regarding training is crucial for the support of new training for workflow implementation.

Understanding Labor Reporting

The first management process modeled was labor reporting. Labor reporting and the payroll process is the least complicated support process examined as part of this research. However, failure to properly document labor activities has several severe consequences for a firm. Legally, a firm can be forced to pay for back wages or overtime pay, in addition to any taxes and penalties assessed, due to employees for hours of work performed for the company, but that were not recorded. Historical data, used for estimating future projects or determining the profitability or cash flow needs of the current project, may be flawed. For time and material based contracts, labor reporting may be of critical importance for owner reimbursement as part of the contract. Fraudulent reporting of "ghost" or non-existent employees may also inflate payroll costs. Monitoring of labor activity is crucial for determining resource use and productivity. Labor cost is the most difficult variable for controlling costs in construction and must be carefully monitored. As noted by Anderson & Woodhead (1987, p. 279), "on larger projects, where a large complement of manpower is used, the documentation of field data becomes essential to any understanding of the effectiveness of project activity."

Labor reporting can be broken down into two general areas as shown in Figure 4-1. The first area deals with the raw time sheet data (e.g., who is working and what did they do) determined by the labor activities performed by the General Contractor's employees on the project jobsite in addition to how this labor data is reported. The second area deals with the analysis of and evaluation of the information collected. Since labor reporting begins in the field, four questions need to be answered for understanding and development of a model of this process. These questions are summarized in Table 4-3:

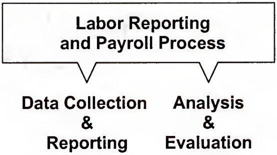

Labor Reporting and Payroll Process
Data Collection & Reporting
Analysis & Evaluation

Figure 4-1. Two areas of understanding the payroll process.

Table 4-3. Basic questions about labor reporting on the jobsite.

1). Who collects the raw data?
2). Who is responsible for coding that raw labor data?
3). Who is responsible for transmitting that raw data to the office?
4). Who is responsible for entering it into the accounting system within the office?

Not surprisingly, of the six companies that collect labor data, all report that the project Superintendent is responsible for the collection of the raw labor data. This may come from reports that the Superintendent has developed, labor crew leaders, or personal observation notes (e.g., back of the envelope notations). Typically this information will be manually recorded by the Superintendent on a summary company time sheet form for the entire project that includes the field employee's name and coding for work activities for a given day. This form is then given to the payroll office for processing into the accounting system.

Labor coding of activities is one of the most important activities of the labor reporting process, but commonly given the least amount of attention. Labor codes provide a method of tracking labor spent on a particular field task or work activity for the purposes of tracking costs of that task or activity. It is the responsibility of the person coding the labor activities to make sure that labor is correctly accounted for the proper activity classification. Documentation of labor activities is the source of all estimating, scheduling and productivity decision making. Incorrect coding of work activities, either not to break the budget on a particular labor task or because of misunderstanding of exactly what a labor activity should be classified, as are serious problems that must be prevented. Workflow cannot prevent outright fraudulent reporting, but can provide a method to reduce incorrect coding by providing a built-in definition labor dictionary to assist whoever is doing the labor coding in the jobsite office.

Nearly all companies reported that the project Superintendent was responsible for transmitting labor data to the office. What is important to note, however, is the *method* of collection and transmission to the office. Typically, this is done by having someone hand carry the paperwork to the office or by fax transmission. Transmission of raw data manually requires that a second individual must enter the data into the payroll system which leaves open the change of error due to keypunching mistakes, possible delays in code entry because of garbled handwriting or fax transmission, missing information, or delays for approval from an unavailable Project Manager. Furthermore, this adds additional cost to the labor reporting process.

Two companies, however, FLD and Q and Q Construction, have their Superintendents enter labor data directly into their companies' payroll systems through the use of dial-up connections and jobsite trailer computer modems. This eliminates the possibilities for error discussed previously. Direct transmission of payroll information into the accounting system also opens the door to providing intelligent support to the field Superintendent or other employee (e.g., Time Keeper, Project Clerk, Secretary) charged with entering raw data into the payroll system.

The next step in the investigation of labor reporting moves from the field to the office where the raw data is to be entered into the payroll system and transformed into the useful information, e.g., summary labor reports, productivity reports, schedule updates, etc. and the writing of payroll checks. This process, which splits into two parts, is graphically summarized in Figure 4-2.

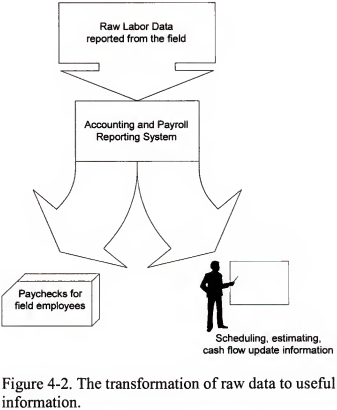

Raw Labor Data reported from the field
Accounting and Payroll Reporting System
Paychecks for field employees
Scheduling, estimating, cash flow update information

Figure 4-2. The transformation of raw data to useful information.

A summary of actions for data entry of labor gathered from the firms participating in this research is shown in Table 4-4. At four of the six firms, payroll must be manually entered by the payroll office before the payroll can be run. At two companies, it was found that payroll had to be reviewed and approved by Project Managers before the Payroll clerk could enter the information into the system. At EDO, review and approval is required at several levels because of some significant labor fraud experienced by the firm several years earlier. These additional delays in payroll entry merely increase the contractor's overhead and delay access to the updated project budget information.

Table 4-4. Summary of actions for entry of raw labor data.

Activity	**Count**
Payroll entered directly by Superintendent	2
Payroll entered by a Payroll clerk directly from field time sheets	2
Companies that require additional review before payroll entry	2

"What "processed information" and *when* the processed labor information is examined and reviewed are questions that must be answered understand the labor reporting process. Table 4-5 provides this breakdown in the six companies examined that carry a labor force.

Table 4-5. Breakdown of summary labor reporting needs.

Position - Title	Weekly Report	Monthly Report
Project Manager [a]	4	6
Upper Management [b]	0	6

[a] Project Manager or equivalent as some firms do not have a position of Project Manager.

[b] Upper Management in this instance includes persons holding the title of Vice President, President or Operations Manager. At BBB, the President of the company also serves as a Project Manager on some projects.

In four of the companies interviewed, it was reported that each Project Manager receives a weekly summary of labor spent on their projects. At these same four companies, Project Managers receive monthly summary reports on labor activities on their projects (e.g, total labor cost). Surprisingly, however, at two firms, Project Managers do not receive weekly labor reports, but only monthly reports therefore at these two companies, cost overruns for work activities or labor problems may be thirty days old before Project Managers are aware of any problems. At all six companies members, of upper management (e.g., President, Vice President, Operations Manager) receive summary information regarding labor spent on projects every month.

The actual reporting needs or factors that each Project Manager may examine as part of the weekly and monthly labor reports, as well as the amount of time spent reviewing labor cost, varied considerably from managers within firms. Typically "overrunning of labor cost" on a line item was the most common factor said to be examined. However, the concept of overrunning cost has several heuristics, such as tradeoffs for extra work performed on the project site for the owner or a subcontractor, that may be involved that were not examined as part of this research, but must be considered. The other factor identified as part of the weekly review process was the amount of time or attention to detail spent. Particularly busy Project Managers running multiple projects spent little or no time on labor review for their smooth running projects. Instead, they focused their attention on projects where the schedule had fallen behind or labor cost overruns were already in happening or forecasted to occur. Where the projects involved more maintenance of owner facilities and little change in weekly labor activities, Project Managers spent little or no time on reviewing these "quieter" projects.

The other commonly mentioned action performed as part of the monthly review process of labor, either at the Project Management level or as one of upper management's responsibilities, was the development of some type of labor forecast. All of domain experts at the six companies that collected labor data said that some form of labor analysis needs and projections were developed every month as a regular part of their company's review of labor spending and payroll. Two reasons were provided for this analysis of labor spending. First, upper management desires to better control of their firm's labor costs by reducing the amount of actual field employees on projects. Second, the available labor pool for many trades is particularly tight. For construction firms with large project backlogs, it is critical for member of upper management to ensure that they have the necessary and available labor force required on their projects.

Check distribution was the other outcome of the labor reporting process. Five of the six companies interviewed have a formally assigned individual within their payroll or Accounting department to handle this function. However, at FLD Construction, payroll checks are printed in the job trailer, while the jobsite computer is on-line, and counter signed by both the project Superintendent and the project Field Clerk. The Field Clerk is then required to fax back to the office the confirming check numbers. This provides the firm an immediate significant savings on overnight carrier shipping fees which averages 22 dollars per project per week as well as office overhead.

Analysis of the Request for Payment Process

The request for payment process is one of the most critical for the management of a construction company. The request for payment is the construction industry's method of billing a client for work performed at a prearranged time for all work completed during the previous month (Fisk, 1992). If the submittal requirements for a request to the owner for progress payment is not properly made out (i.e., back up receipts are not provided, minority hiring information required is missing or incomplete) the construction contractor may find that the request for payment is denied or reduced. It should be noted that the method of request for payment discussed as part of this research were based on lump-sum contracts and not unit-price contracts more commonly used in engineering contracts.

As shown in Figure 4-3, the internal company agents contributing to the monthly Request for Payment from the contractor vary widely in terms of their contributions. Obviously, not every firm has a position of scheduler. However, some person within every firm fulfills this function. Despite the range of characteristics of each company interviewed as part of this research, tremendous similarity exists among companies in terms of how they conduct the request for payment process.

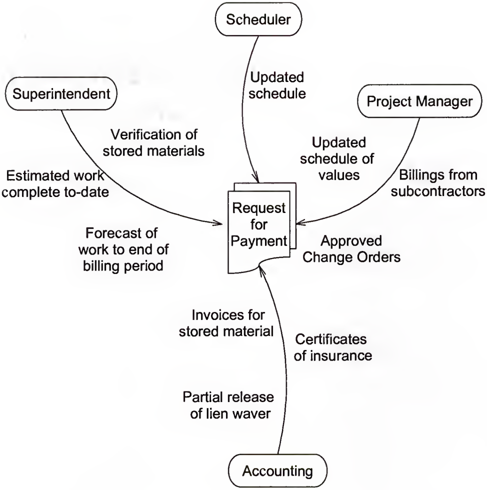

Scheduler
Updated schedule
Superintendent
Project Manager
Verification of stored materials
Updated schedule of values
Estimated work complete to-date
Billings from subcontractors
Request for Payment
Forecast of work to end of billing period
Approved Change Orders
Invoices for stored material
Certificates of insurance
Partial release of lien waver
Accounting

Figure 4-3. Schematic illustration of the factors involved in the monthly Request for payment by a construction contractor.

The activities that make up the request for payment process can be classified into three broad overlapping categories as labeled in Figure 4-5. The most significant difference found was the internal makeup of the request for payment process specific to each company.

Table 4-5 shows the summary of actions required for any workflow implemented request for payment process. There are, typically, only three actors directly involved in

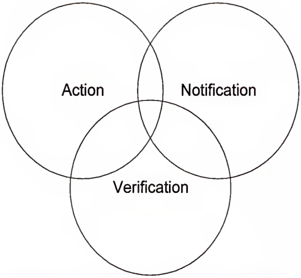


Figure 4-4. Categories of activities involved in the request for payment process.

the Request for Payment process: the Superintendent, Project Manager and the Accounting department. The formal position of scheduler has been left out because in the companies examined as part of this research only one reported having a formal scheduler position.

Analysis of the Change Order Process

The Change Order Process was the third process decomposed and examined as a part of this research. As with the request for payment process discussed earlier as a part of this chapter, the Change Order process is very specific in terms of reporting procedures within each company. Additionally, however, the Change Order process is very heavily governed by the policies of the particular client. Some clients do not wish for multiple small Change Orders; instead they require that Change Orders be bundled together as one large request for additional monies. For example, in large firms that have

Table 4-6. Summary table of the actors and actions required in the request for payment process.

Superintendent	1. Estimates of work completed to-date	1. Work of subcontractors	1. P.M. of stored materials
Project Manager	1. Updates contract budget (from approved change orders) 2. Revises schedule of values 3. Reviews subcontractor billings 4. Projection of work to end of pay period	2. Work complete on project with Superintendent	3. Upper management notified of amount of billing on each contract
Accounting	1. Mails letters of non-compliance to subs 2. Revise budgets after payment from owner	1. Certificates of insurance/license of file from subcontractors 2. Partial release of lien wavier from subs	1. Subcontractors missing insurance/licenses 2. PM of subcontractors tardy with lien waivers 3. Upper Mgmt. of billings and payments received
Upper Management	1. Cash flow forecasts		
	Action	Verification	Notification

a set budget for construction of new facilities, the Owner's Construction Manager can more easily go back and ask for additional monies to be allocated for construction because of a larger singular change (e.g., change in building design) than a number of smaller problems (e.g., change in color of paint on walls that have already been painted or a change in the type of lock sets to be installed in doors).

The Change Order request process is also governed by the initiator of the request. There are four sources for Change Order requests as summarized in Table 4-7:

Table 4-7. Sources of change order requests.

Subcontractors
Vendors or suppliers
Owner or Owner's representative (e.g., Construction Manager, Architect, Engineer)
General Contractor

This researcher found that subcontractors that are over budget and behind schedule are more likely to file for a Change Order request either for lost profit or time extensions. A second source of Change Orders are those that may be requested by the owner or design team for the project. The cause of these requested changes ranges considerably and cannot be easily quantified.

A third source of possible Change Order requests is from vendors or suppliers for the General Contractor or subcontractors on the project. It is not atypical that a manufactured item is unavailable or obsolete before it is needed for installation in a project because of dated specifications or change in the manufacturer's line.

Furthermore, there may be additional changes required for specially engineered equipment for a particular project that may be required thus generating the need for a Change Order. The fourth source of Change Order requests comes from the General Contractor. The General Contractor may initiate a Change Order request for a variety of reasons including hidden conditions, change in contract scope, and weather delays.

However, careful examination of the Change Order process as detailed by the domain experts interviewed as part of this research provides the 15 item content analysis summary found in Table 4-8. The initiation of the Change Order request, at the General Contractor's level, always begins with recording of the Change Order request in some type of log system, which permits the contractor to track the Change Order requests. The decision rules that are applied can be converted into two parts: 1) Action rules, 2) Check or verification rules.

Action rules are what this researcher defines as rules which if affirmative require an action on the part of the actor. For example, the decision rule "perform scope analysis" is an action rule based upon information gathered from an earlier series of questions. The action rule reminds the Project Manager, or person working with the workflow system, to make a scope analysis of the proposed Change Order under question. For purposes of this analysis, it has been presumed that the Project Manager will be the person initiating the Change Order request. In practice, this may be an Assistant Project Manager or a Superintendent in the field. The actual workflow system installed may permit multiple points of entry depending upon the particular structure of the company.

Table 4-8. Content analysis summary table for the change order process.

#	Actor	**What your actions do you take?** (What do you do here)	**What decision rules do you apply** (Judgement or verification procedures)	**Whom do you hand pass the information to?**
1	Project Manager	Receive request for change order	Who made request? Will owner "buy" the request? Can the request be "supported?" Is the request "fair?" What does the contract say? What does the owner say (or history of acceptance)? Is it worth the trouble/time/effort?	
2	Project Manager	Log request/assign tracking number	None	
3	Project Manager	Get price information	Perform scope analysis. Do I need an estimator? How will change order affect schedule?	
4	Project Manager	Estimate work (scope analysis)	Is everything covered? What subcontractors or vendors need to be contacted?	Subs/vendors (outside of direct company process)
5	Project Manager	Write/submit formal change order	Is all information here? Will the owner "buy" the request?	Architect Const. Manager Owner's Rep. Owner
6	Owner or Owner's rep.	Decide to accept or reject Change Order request		Project Manager

Shaded area indicates a step outside of the constructor's control, but still part of the process.

Table 4-8--continued.

#	Actor	**What your actions do you take?** (What do you do here)	**What decision rules do you apply** (Judgement or verification procedures)	**Whom do you hand pass the information to?**
7	Project Manager (if rejected)	Record rejection in log	Will this change schedule? Reexamine scope Revise change order proposal?	Superintendent, Subcontractors
8	Project Manager (if accepted)	Record acceptance in log	Does the schedule require updating? Does upper management require notification? What subcontractors require a change order? What vendors require early notification?	Superintendent, Subcontractors, Accounting
9	Project Manager	Notify Accounting of change	None	Accounting Dept.
10	Project Manager	Create/file copies	Who must be notified?	Job files, Superintendent, Contract files (accounting)
11	Superintendent	Updates schedule	Check current schedule against approved C.O.	Project Manager
12	Accounting	Revise Project Budget	None	Project Manager, Upper Management
13	Project Manager	Issues Change Orders to Subs	What subcontractors required to be contacted?	Subcontractors, Accounting
14		Issues Purchase Orders to vendors	What materials, equipment, supplies are required?	Vendors, Accounting
15	Upper Management	Review project budget	Compare to estimate and schedule	

Check or verification rules are defined by this researcher as rules that provide reminders to the Project Manager. For example, the check rule “what subcontractors need to be contacted” could be additionally attached with a list of major subs on the project or a content sensitive “intelligent” agent that has the ability to scan the Change Order; and based upon key words, develops a pop-up list of subs that the work affects.

Concluding Remarks

Chapter 1, Introduction, provided a brief overview of the research and the problem statement. Chapter 2, Literature Review, covers the background of workflow technology, how workflow is tied to Total Quality Management and a brief introduction to expert systems.

This chapter has provided an analysis of the information collected during the interviews with domain experts of eight General Contracting construction companies in the United States. The three major support processes of labor reporting, request of payment for work performed, and change order requests were decomposed using the workflow analysis technique of process mapping to determine the common elements among the firms participating in this research. These common reporting and decision making elements form the basis of “to-be” process models that graphically display the reengineered processes after the installation of intelligent workflow to manage each process. The case studies developed from the “as-is” process models are presented in the Appendices.

Additionally, the level of computer usage sophistication at each company was examined and the results presented as part of this chapter. An understanding of each firm’s level of computer usage is necessary to understand the current method or reporting that has developed at each firm in addition to other policies or procedures that each firm has developed over time.

Chapter 5, Conclusions of the Study, examines the scholarly contributions to the field of construction management and research by highlighting the contributions provided by this study. The three “to-be” process models, based upon the analysis presented in Chapter 4, are presented as part of this chapter. Chapter 6, Future Research, provides suggestions for future researchers based upon the research issues found here.

CHAPTER 5
CONCLUSIONS OF THE STUDY

The construction industry is different from other industries in that decision-making requires substantial amounts of data that must quickly cross through two completely different process levels (one in the field and one in the office) in order to be both effective and timely. Previous research in modeling processes and the development of expert systems for use in the construction industry, as discussed in Chapter 2, have focused almost exclusively on either field level or office level decision making, one to the exclusion of the other. This research has gone beyond that type of singular focus to provide a more holistic picture of what is actually occurring by examining what happens as these processes cross from the field into the office. The crucial support processes of the construction firm labor reporting, request for payment, and handling of change orders were critically examined with the intent of providing future researchers with the ability to implement an intelligent workflow to control the process.

It is impossible, as noted by Yin (1994) to generalize case study evidence from a limited number of cases such as those contained within this dissertation. Particularly in an industry that is noted for it fragmentation and divisiveness because of the differences in scope and size of work performed (Barrie and Paulson, 1992). However, this research is strengthened by the fact that similar observations were made at each firm within the study group.

The company participants in the study, despite the fact that they represented different geographical areas, company size and ownership structures, were found to have very similar processes that, when modeled at a higher level, were found to produce nearly the same model in terms of reporting requirements, product outcomes, and results. It is therefore possible for this researcher to still draw some conclusions for discussion and future testing that apply across all facets of the industry at least meeting the basic criteria for inclusion into the study as set forth in Chapter 3.

The conclusions presented and the hypothetical models developed are evolved from the iterative inductive-deductive cycle of analysis for qualitative research described in Chapter 3. As presented here, the conclusions and process models created are not stated in a form that facilitates their testing through the use of quantitative analysis methods. They represent the summary description of perspectives held by the process participants at each firm.

Some of the conclusions may appear to be intuitively obvious to the experienced contractor. These hypotheses are however, still important outcomes of the study which has produced hard evidence as validation for the intuitively obvious. Three conclusions were drawn from the study.

Conclusions of the Study

One. *The existing processes are time intensive.* One common theme of all interviews was the feeling of being pressed for time or constantly working under extreme deadlines. The existing processes, at the firms studied, require enormous amounts of contact time on the part of the process participants and the data that they are handling. Sorting, filtering, selection, and filing are virtually all manually conducted operations that employees at the firms studied must conduct. Some of these activities are required to be performed on a daily basis. All are required on either a weekly or monthly basis depending upon the reporting needs of upper management and the company clients.

One extreme example, is the following comment made in response to an interview question by the researcher on how often the data is collected and handled:

> You just cannot imagine what the pressure is like around here. Rush, rush, rush every day. I have four projects to juggle each with their own superintendent, workforce, problems and clients. I work seventy hour work weeks regularly. The crunch is at end the end of the month when we have to get our payreqs in to the owner. Nothing goes out of here without my boss seeing every piece of paper. Which just slows everything down even more.

The constant theme of work under pressure or constant deadlines because of onerous labor demands placed on employees at the firms leads to conclusion two.

Two. *The existing processes are labor inefficient.* The existing processes require extensive manual interaction in terms of data entry, sorting, filtering, selection and filing. The existing processes require human interaction at nearly all levels, even in the most sophisticated computer integrated firms. This is a poor use of crucial human resources that are in short supply. The net effect of the labor inefficiency prevents construction firms from producing a lower cost product because of the higher overhead cost that must be carried by the contractor.

Three. *Of key importance is the accurate and timely reporting of information due to the highly contractual nature of the work performed.* Nearly all persons interviewed as part of this research discussed the importance of reliable, factual, and timely generated information to project managers and members of upper management.

An additional consideration discussed by several domain experts was the importance of proper documentation for extras provided by the contractor and the notification to the issuing surety company for additions or changes to the scope of the work. The existing procedures in place at the firms investigated do not provide for automatic verification, distribution or notification of critical data. It is presumed by the domain experts that such information is distributed only when and if it becomes necessary.

Study Outcomes

With the identification of the three conclusions presented above, it was possible for the researcher to develop generic hypothetical "to-be" process models for future testing by construction industry researchers. The theoretical models are developed with the idea of the expert system controller managing the workflow processes within the construction firm.

The "To-Be" Workflow Labor Reporting Process

Figure 5-1 shows the reengineered workflow labor reporting process based upon the information gathered as part of this investigation. In the "to-be" model, raw field data is directly entered into the payroll program by the superintendent. The collection of raw data by the superintendent is facilitated by the expert system monitoring the input of labor coding to ensure correct compliance and improve historical data. The only action necessary by the payroll department is the physical separation of the payroll checks.

All job files are automatically updated. The "to-be" workflow process allows for dynamic sorting of labor information for both upper management and for project managers. Data reports can be automatically created and updated. Labor force

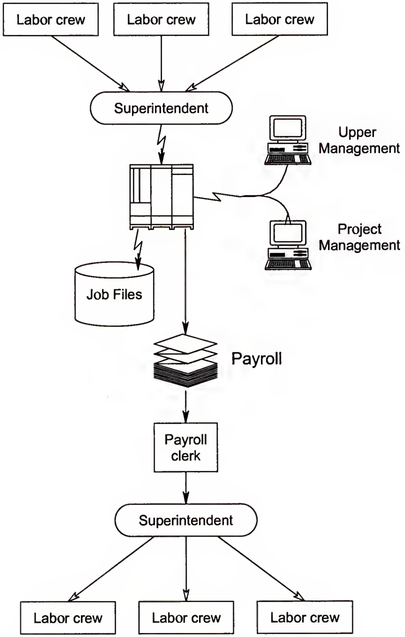


Figure 5-1. "To-be" workflow process model for labor reporting and payroll.

projections can be created by the system and automatic reporting functions built-in to notify Project Managers of hiring needs in terms of particular skilled trades. Specific reporting needs for Project Managers (e.g., Union required raises) can be met by appropriately filtering the data. A side by side comparison of the generic workflow model adapted to meet the needs of each of the companies with field employees is presented in Appendix N.

The "To-be" Pay Request to Owner Process Model

The "to-be" process model of the Request for Payment to the owner is shown in Figure 5-2. As can be seen in examining the model, the notification steps listed in Table 4-5 are eliminated by allowing the workflow system to automatically handle those routing requirements and the actions required of the persons involved in the process. Verification reminders for a specific process become automatic as part of the system. The files for subcontractors monitored for expired certificates of insurance or licenses and letters requesting their renewal are automatically generated. Specific forms or information required to be submitted each month by contract (e.g., updated schedule, minority contractor participation forms) can be printed out with the information required already in place or revised as changes occur. Budgets are automatically updated once accounting has entered payments received from the owner.

With the Superintendent automatically updating the schedule from the field, the Project Manager can concentrate on reviewing invoices from vendors or bills from subcontractors that are requesting payment. Members of upper management are automatically updated regarding projects and the company financial strength in terms of the pay requests, payments received, and retainage held. Forecasts for cash needs can be run and updated automatically. Potential delays or confusion on the development of a request for payment to a particular client because of the absence of the Project Manager

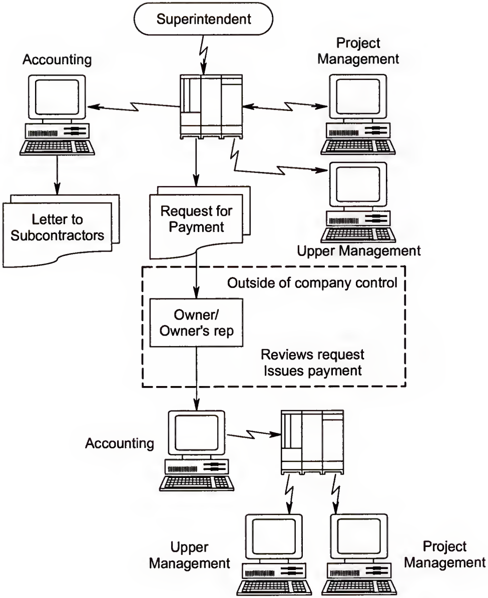


Figure 5-2. "To-be" Workflow controlled request for payment process model.

is minimized because the system can pull together most of the parts of the pay request asynchronously and without human intervention. The accounting and scheduling is updated daily as new information is entered into the system. Consequently, the end of the month pay request to owner is nearly completed when the Project Manager prepares to develop the monthly request for payment to the owner.

Owner specific contractual requirements (e.g., specific reporting forms, analysis of the draw request, or schedule updates) can be met by building owner specific rule base modules that can be plugged into the overall company rule base that is only triggered by simple test or verification questions. An example question might be "is the contract issued by the Department of Defense?"

The "To-be" Change Order Process Model

Examining Figure 5-3, one can see that the multiple notification and approval process commonly found in construction firms, as indicated by the process models developed for this research, is eliminated. Once entered into the Change Order request workflow system, the intelligent system can handle notifications and, given the correct parameters, develop requests for pricing information by subcontractors or vendors. The system will automatically handle updates and produce a "tickler" or reminder file of notifications for the Project Manager if action has been slow on the part of a client regarding a particular Change Order.

Once a decision has been made by the project Owner, that decision can be entered into the system by the particular Project Manager or a trained Administrative Assistant. The workflow system automatically adjusts subcontractor budgets and issues purchase orders to vendors for missing or additional materials. Furthermore, the workflow system can update the project schedule and perform updated data analysis on the financial information of the project to produce current cost records and reports.

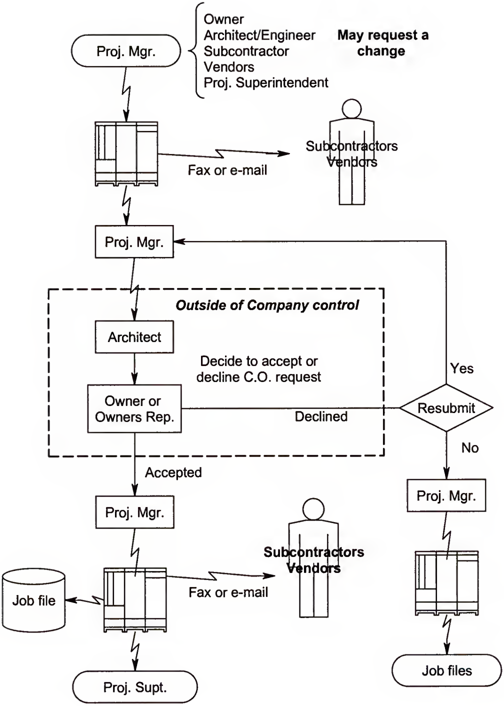


Figure 5-3. The change order process after workflow implementation.

Chapter Conclusion

The study has provided two significant contributions to the knowledge base of construction First the processes of labor reporting, request for payment and change order requests that are so common in the construction are examined holistically. The symbolic models of these processes are developed in order to implement and evaluate the reengineering of existing processes with the intent of implementing workflow. The "to-be" models developed are based upon the information collected during interviews with the employees of the construction firms that agreed to participate in the research and analyzed as outlined in Chapter 3, Methodology.

The second contribution has been the identification of detailed activities, validation rules, and tasks forming each of the processes studied. This research has resulted in the identification of key business rules that must be included for the greatest potential for process improvement to occur and are necessary for inclusion in an expert system controlled workflow process. This has been done through the examination of the same basic processes at multiple firms to develop a stronger reinforced view of how each process works within the industry as a whole instead of just one company. The analysis of these key business rules is presented in Chapter 4.

Chapter 1 discussed the problems that construction industry continues to grapple with the implementation and utilization of advanced information technologies like an expert system-controlled workflow. As explained in Chapter 2, Literature Review, information needed to make critical decisions is bottled up because of the long and arduous processes of converting mountains of raw data into the cupful of management information necessary for correct decision making. Intelligent workflow systems will provide a mechanism for handling the flood of such critical information and facilitate the decision making process for overwhelmed construction management professionals. By building knowledge based expert systems that have the ability to replicate the thinking of the experts for decision making and for routing only the needed information when required and to the correct person, workflow technology will not only dramatically reduce contractor overhead, but also help minimize problems due to poor, uninformed decision making.

CHAPTER 6
FUTURE RESEARCH

This chapter examines some areas of potential future research that were not examined as part of this analysis, but may increase the employment of workflow technology applications and their use within the construction industry. Four areas for future research were identified: software development, demographics of companies and domain experts, generalizabiltiy of the findings, and the impact of the Internet on collaborative communication efforts.

Software Development

One area that was not examined in the research was fact that some firms have been successful in writing and using their own software applications. In-house software, programs a firm has developed from scratch for its own use, may be used in accounting, project management, or project analysis, for example. In-house development of these types of programs suggests a high level of computer sophistication and knowledge among members of upper management that is critical for acceptance of workflow tools. The construction industry is often viewed as extremely unsophisticated in the use of information technology. Most research presented in the area of workflow and expert systems is confined to academics working on pushing the envelope of information technology. Potential development efforts with a construction firm that has experience with software development and implementation of these systems would be a good crucible for developing expert system-controlled workflow applications. This area of research is one that large firms, that maintain their own software development teams, may endeavor to explore on their own.

Demographics of the Companies and Domain Experts

Better understanding of the demographics of the companies using advanced information technology applications is suggested. Anecdotal evidence suggests that the type of company ownership may hinder or encourage the use of workflow technology within the construction industry. This was not considered in the literature research, but several people interviewed as part of this research said this was a consideration. The ownership structure may provide more answers why they have not adopted workflow applications.

Generalizability of the Findings

Because of the limited sample size of this study, one must ask if these rules apply to all construction firms meeting the criteria stated in Chapter Three. Is there a more focused area of the construction industry that may have a different set of reporting criteria than that found in the research? Most of the firms included in this research were building contractors and not specialty engineering firms, e.g., Bechtel, Fluor Daniel. Accordingly, specialty engineering firms are another element that needs to be included for proper development of workflow systems that was not covered in this research and requires further investigation.

The Impact of the Internet on Collaborative Communication

The impact and size of the Internet, or World Wide Web, continues to be growing quickly affecting contractors, subcontractors, designers, engineers, architects and building owners in a variety of ways. The ability of the smaller contractor to take advantage of the Internet, for collaborative workflow, is considered by many to be a significant advantage over the large contractor that has a significant investment in computer hardware, software and employee training. Furthermore, newer, less expensive, technically more powerful, groupware tools and expert system shells that are designed to take advantage of the Internet are introduced into the marketplace each year. What effect these tools will have on the construction business and existing management practices are unknown and will require future research.

Summary

Workflow applications with expert system support and control provide an exciting area of research and application. These systems potentially could be extremely useful to the construction industry for dealing with the paperwork and information flow that must be tamed if contractors are to build successful, profitable firms. More responsive construction professionals provide a benefit to all of society by being able to concentrate on the job at hand better: building quality facilities.

APPENDIX A
SAMPLE AGENDA

1. Introduction to research project - Charles Duvel

2. Overview of Acme's business (volume, types of customer, types of projects)

3. Overview of Acme's company structure (organization chart, roles and responsibilities of each person, etc.). Policies and procedures manual, if available, is useful here

4. Acme's use of computers, networks, and information systems
    a. Level of use of computers by the firm
    b. Training provided
    c. Software programs run (both project management specific and non project management)
    d. Decision Support mechanisms, Expert systems, Groupware applications
    e. Implementation problems and solutions developed

5. Acme's process for labor reporting
    a. Responsibilities of each person/department
    b. Transmission of information
    c. Approvals/sign-offs
    d. Documentation
    e. Feedback/control mechanisms

6. Acme's process for handling change orders
    a. Responsibilities of each person/department
    b. Transmission of information
    c. Approvals/sign-offs
    d. Documentation
    e. Feedback/control mechanisms

7. Acme's process for handling requests for payment to owner
    a. Responsibilities of each person/department
    b. Transmission of information
    c. Approvals/sign-offs
    d. Documentation
    e. Feedback/control mechanisms

8. Interviews with Acme Construction staff employees (if necessary)
9. Conclusion and final comments

APPENDIX B
PROCESS MODEL QUESTIONS

General Company Questions

Name of company (or subsidiary)
Tell me about the firm's organizational structure?
What is your job title or function?
What type of contract work does your firm primarily do?
What type of work is performed by your employees?
Types of workgroup applications used (e.g., e-mail, Lotus Notes)
How long have these applications been used?
How many people have access?
How are these groups broken down (e.g. by project management groups, task groups)?
Is any type of workflow applications being used?
Is there any document imaging software being used?

Process Questions

What do you do here? What are your tasks?
What do you do with the forms (e.g, spreadsheets)?
What are the requirements of the process you described to me?
How is the information collected?
Where is the data collected?
Who is responsible for collecting it?
How often is the data collected?
Why?
Who handles the information?
Who else may get a copy of the transformed data?
Who else may get a copy of the raw data?
How do you know when the process is completed?
How often is the data handled?
What are the transformation steps from data to information?
What do you do with the collected information?
Who is responsible for its completion?
Are sufficient resources allocated to each process?
What time requirements are there if any on this process?
How long does one cycle of the process take?
Are the interfaces between processes managed?

What are the specific roles and responsibilities of each person within the process?
What does that person do with the data next?
Where does this information come from?
How is it transmitted to that person (or you)?
What happens if that person is not here?
Why is the process done in this way?
How is the data or information verified?
What verification procedures are involved?
Who verifies the information?
How often is the information verified?
How accurate is the information you get?
How do you find errors?
What causes you or someone to verify information received?
Who is responsible for that?
Why is it done then or at that time?
How do you fix that problem?
How are problems or conflicts with information handled?
Who makes that decision?
What signoff is required to show that the process is completed if any?
Who signs off?
When do they that do that?
Do these people actually review the documents or do they make substantive changes?
When were these systems implemented?
When were they revised last, if at all?
What caused the revision in the process?
What legal or other "outside" constraints (e.g., collective bargaining agreements) apply to the process you have described to me?
How closely does the process you have described follow the company procedures manual?
What suggestions would you give to make the process easier?

Ownership Questions

Who "owns" the process?
How do your internal "customers" impact the process?
Does the owner of the company review the data or the transformed information?
How long has the process been in this manner?
How is the process revised?
Who is responsible in revising it?
Whom else may be involved in revising the process?
How often is the process revised?
Why was the process revised from the previous way it was handled?
Are these the same for all locations or is there location or owner specific procedures, forms or requirements that must be met?

Culture Questions

Is the data collected manually or electronically? Why?
Is there a written company manual about that process?
Is the company manual followed?
How do new employees learn the process?
Is training provided so people know the process?
How often is this training provided?
In your opinion is the training provided adequate?
Who received training?
Is new training ever completed or refresher training provided?
Is training mandatory or voluntary?
Who provides the training?
What type of work is performed by your employees in your department?
Types of workgroup applications are used (e.g., e-mail, Lotus Notes)?
How long have these applications been used?
How many people have access to the system or network?
How are these groups broken down (e.g. by project management groups, task groups)
Is any type of workflow applications being used?
Is there any document imaging software being used?
Does your firm use any expert system programs?
In order to implement workgroup applications did your firm develop process models?
Does your firm use any expert system applications?
Does your firm use any electronic decision support systems?
Does your firm use any type of project management software for scheduling purposes?
Does your firm use any electronic spreadsheet systems?
Does your firm use any type of document management software?
Does your firm use any form of electronic databases?
Of the programs you have described to me . . . what training is provided for their use?
How often is this training provided?
Is it done internally or externally?
What prompted the use of that particular software?
When were these systems put into place?
When were they revised last?

Current Analysis Questions

What do you receive?

What reports do you currently get?
Which ones do you use?
How often do you receive this report?
What do you look for?
What else do you do with this?

What do you create?

What reports do you create?
Do you make substantive changes to reports you receive?
How often do you perform this analysis?
Who gets this information?
Do other groups or individuals create this same report? If so, who?
How is it used?
How long does it take for you to create it?
Where do you get this information?
If you had the time, what are the next steps you would take to analyze this information?

Data Specific Information

Where does this data come from?
How often is it updated?
What level of detail in included?
Who is responsible for it?

APPENDIX C
COMPUTER USAGE SURVEY FORM

No Yes
1. ___ ___ Does the company use project management software (for example P3, SureTrack, MS Project, etc.)

2. If yes, who uses this type of software in the firm (please check all that apply)

Others __ Project Managers __ Superintendents __ Schedulers __

3. If yes, is training provided for its use? Yes __ No __

No Yes

4. ___ ___ Does the company use some type of document management software (ex. Expedition, Wellcom's Open Plan, etc.)?

5. If yes, who in the firm uses this software? (Please check all that apply)

Estimators __ Project Managers __ Superintendents __
Upper Management __Office Engineer __ Other __

6. If yes, is training provided for its use? Yes __ No __

No Yes

7. ___ ___ Does the firm use spreadsheets for project tracking (e.g., labor forecasting, cost control, etc)?

8. If yes, who in the firm uses this software? (Please check all that apply)

Estimators __ Project Managers __ Superintendents __ Upper Management __
Office Engineer __ Other __

9. If yes, is training provided for its use? Yes __ No __

No Yes
10. ____ ____ Does the firm use spreadsheets for estimating purposes?

11. If yes, who in the firm uses this software? (Please check all that apply)

Estimators __ Project Managers __ Superintendents __ Upper Management __
Office Engineer __ Other __

12. If yes, is training provided for its use? Yes __ No __

No Yes

13. ____ ____ Does the firm use some type of "specialized" estimating software package (e.g.,Timberline, MC^2, WinEst, etc.)?

14. If yes, who in the firm uses this software? (Please check all that apply)

Estimators __ Project Managers __ Superintendents __ Upper Management __
Office Engineer __ Other __

15. If yes, is training provided for its use? Yes __ No __

No Yes

16. ____ ____ Does the company use some type of "groupware" application (ex. Lotus Notes, e-mail, electronic white boards, video conferencing, etc.)?

17. If yes, who in the firm uses this software? (Please check all that apply)

Estimators __ Project Managers __ Superintendents __ Upper Management __
Office Engineer __ Other __

18. If yes, is training provided for its use? Yes __ No __

19. Please write in the space provided what types of applications are being used in your firm?

____

20. How long have these types of applications been in use by the company?

< 1yr.___ 1-2 yrs. ___ 3-4 yrs. ___ 4-5 yrs.___ 5-6 yrs. ___ 7-8+yrs. ___

21. Applications or programs for groupware are designed by: (check all that apply)

    In-house staff________ Outside consultants ________
    Off-the-shelf _______

No Yes
22.____ _____ Does the firm use any rule based expert system programs (or shells) for decision making support?

23. Please write in the types of problems the expert systems are being used to answer (e.g., safety, planning, bidding, etc.).

    ____

24. If yes, is training provided for its use? Yes __ No __

No Yes
25. ____ ____ Does the company use databases?

26. If yes, is training provided for its use? Yes __ No __

27. The firm uses databases for the following (please check all that apply):
28. ___ Employee tracking (ex. work history, training, etc.).
29. ___ Subcontractors (ex. names, areas worked, insurance, etc.)
30. ___ Paper log or document tracking for job submittals, C.O.s etc.
31. ___ Materials tracking
32. ___ Estimating purposes
33. Other please write in

    ____

34. ____

No Yes
35. ____ ____ Does the firm use a computer network in the home office?

36. The people that are on the network include (please check all that apply):
    Estimators _____ Project Managers______ Superintendents_______
    Upper Management ______ Office Engineer ______ Administration ______
    Marketing ______ Accounting_____ Scheduling_______ Purchasing______

37. Is training provided for use on the network? Yes __ No __
38. Does the firm have its own "intranet"? Yes __ No __
39. Does the firm have Internet access? Yes__ No __
40. Do clients have access to the network through a dial-up connection?
    Yes__ No __

41. Do vendors have access to the network through a dial-up connection?
Yes__ No __

No Yes
42. ____ ____ Do the field staff (superintendents, inspectors, etc.) use laptops for transmitting information to the office?

No Yes
43. ____ ____ Are you satisfied with the level of training for computer applications in your firm?

APPENDIX D
SAMPLE LETTER TO CONTRACTORS AND FAX BACK FORM

University of Florida Letterhead

Mr. John Doe
Construction Company President
ABC Construction Company
Any town, FL xxxxx

Dear Mr. Doe:

This letter is being sent to you because (company name) is recognized as one of the leading construction firms in the United States ranking in the ENR top 500 Construction firms.

As you are already know the construction industry continues to be plagued with low productivity, high overhead costs and scarce management resources. One possible answer to these problems may be in the implementation of workflow information technology. I am a Doctoral student at the M. E. Rinker, Sr. School of Building Construction at the University of Florida conducting a research project into the feasibility of this idea. Whether or not your firm uses computers or networked systems for management control of projects, your input is needed. I would like permission to come visit your firm, examine and model how (company name) completes three common management processes: labor recording, handling change orders and processing requests for payment to the owner. Additionally, information regarding the use and implementation of advanced information technologies, like expert systems, would be collected during the company visit. If your company would be interested in participating in this study, please fill out the enclosed form and fax it back to me by March 15th.

Those companies that participate in the study will receive a customized report of the three models developed of their management processes studied. All information shared with this researcher will remain confidential and participating firms will not be identified in the final dissertation publication.

Please take the time to fill out this form so that your organization can benefit from this extremely vital study.

Sincerely,

Charles S. Duvel
Ph.D. Candidate
M.E. Rinker Sr., School of Building Construction
University of Florida
O (352)392-6755
H (352)337-0272
cduvel@worldnet.att.net

Fax Response to Charles Duvel

Workflow Feasibility Study

Fax to (352)337-0272

No cover needed

«Company_Name»
«Street_Address»
«City», «State»
«Phone»

Please make sure that all information above is correct. Please make any corrections necessary.

Check a box please

☐Yes The «Company_Name» would be interested in participating in this study. Please contact:

______________________________ @ ______________________________
(Print contact name above) (Phone number or e- mail address)

to set up dates and times for interviews.

☐No The «Company_Name» would not be interested in participating in this study.

Thank you for your cooperation

Questions? Please contact:
Charles Duvel
Ph.D. Candidate
M. E. Rinker, Sr. School of Building Construction
University of Florida
H (352)337-0272 O (352)392-6755
cduvel@worldnet.att.net

APPENDIX E
OUTLINE OF CASE STUDIES

1. Introduction -
    a. Background of company (e.g., size, ownership, type of work, location)
    b. Processes studied, domain expert and position.
    c. Background of company structure

2. Level of Computer Use
    a. Level of computer usage and training
    b. Network use
    c. Types of software programs used

3. Policies and Procedures
    a. General discussion of the companies policies and procedures

4. Process for Labor Reporting
    a. "As-is" description of how this process is completed
    b. "As-is" Process Model

5. Process for Payment Request to Owner
    a. "As-is" description of how this process is completed
    b. "As-is" Process Model

6. Process for Change Orders
    a. "As-is" description of how this process is completed
    b. "As-is" Process Model

APPENDIX F
EDO COMPANY CASE STUDY

Introduction

The EDO Construction Company is a mid-sized firm which has done approximately 100 million in annual volume for the past 5 years. A mid-western, family-owned firm (third generation), the company specializes in hospital construction work. The firm handles all project supervision in addition to providing the labor for the construction of the building's structure. The processes modeled in this case study include labor reporting, payment request to owner, and change orders.

In 1997 the company, in an attempt to branch out, purchased a small architectural/engineering design firm that specializes in hospital and nursing home facilities. With the addition of the A/E firm, the top management at EDO Construction wishes to move into the design build market by fully integrating the A/E firm into the company's own operations. However, the process models developed do not reflect this change because at the time of the interview sessions the substantive changes in the new company design had not yet been developed.

EDO Construction Company is also involved in two joint venture projects. Neither joint venture is modeled as they are relatively short term in scope, three years or less, and are not permanent partnerships. Other than the joint ventures and project specific offices, the firm does not maintain any satellite offices.

While EDO Construction Company is family owned, according to Robert E___, Vice President for Construction Operations and the domain expert for this case study, each project manager is permitted a large amount of leeway in terms of process controls for projects. However, the process controls examined as part of this study, particularly the Request for Payment, were observed to be under careful scrutiny at all times by upper management.

About 25 - 35% of EDO's work is negotiated, the rest commercially bid. EDO Construction Company takes an aggressive approach to bidding contracts and especially Change Order requests. Many of the projects that EDO bids on are not completely formalized in terms of design drawings and specifications which require a significant amount of conceptual estimating on the part of EDO estimators, Project Managers, and other construction professionals.

Level of Computer Use

The firm, when compared to other companies of this size and sophistication in other industries, is relatively backward in its computer use. Each Project Manager, all members of upper management, and the employees in the Accounting Department have computers assigned to them. However, the firm has to deal with several problems in this regard because computers are not networked and do not have the ability to share information. Nor do all employees (e.g., Project Coordinators and Estimators) have computers or computer access. Likewise, not all employees with computers have the ability to interface with one another because the firm runs differing software and operating systems.

The Accounting Department uses a "retired" IBM mainframe that the firm purchased from a mining company some years earlier and "dumb" terminals. Dumb terminals do not have their own operating systems and are unable to run stand-alone programs like a desktop or laptop computer. One Project Manager, reportedly, still uses only DOS and DOS based spreadsheet and word processing applications. Robert E_____, the domain expert, reports that upper management and the remaining Project Managers use a mix of Windows® 3.11 and Windows® 95 operating systems, and notes that "we're all over the place in terms of other software run."

The company has not formally adopted for use any type of project management scheduling software (e.g., Primavera's P3® , Microsoft Project®, TimeLine®). When project schedules are required by contract, which is not uncommon, these are created by a subcontracted Construction Management firm. One project manager when asked about this reported, "I don't need to use project scheduling software. They are too complicated to learn and use. I just draw out a bar chart for my guys and they know exactly when and where they should be when I want them."

Each project manager is responsible for maintaining his/her own management logs in terms of paperwork that must be completed. Accordingly, some Project Managers have completely paper-based systems, which rely on large columnar pads for tracking submittals, requests, etc. Other project managers have developed their own systems using electronic spreadsheets. When asked about the dichotomy between these two approaches Robert E_____ merely shrugged and observed that:

> "the founder's grandson [and current company President] R__ M______ likes the way things are. We don't bother people that do good work . . . and we don't care how they get those results. Besides, they are always coming out with new software. The 'latest and greatest' thing. We have looked at it and it doesn't meet our needs." However, he also noted that the firm is unable to sustain its growth under the present system and "must change with the times to compete with the big boys. We will be forced to fully put everyone on-line in the next three to five years if we are going to compete. That is just the way things are moving."

Polices and Procedures

Because of the long history of the firm (three generations of family ownership) the company has built up a heavy blanket of rules and regulations that employees must follow. However, in interviews with several employees, a theme began to emerge whereby employees were forced to either ignore the policies and procedure of the firm or develop "work arounds" because the existing processes were not current or were too cumbersome. The following is a sample exchange between the researcher and an employee in Accounting about a purchase order requisition "work around" that is fairly routine in the company:

> **Interviewer:** "According to what I have been told, you are supposed to clear all P.O.s with the Project Manager for the project. Is that correct?"
> **Employee:** "Yes."
> **Interviewer:** "But, what do you when the Project Manager is not here. For example, let's say that Jack is gone. It is Jack C____ right?"
> **Employee:** "Yes."
> **Interviewer:** "Okay, Jack is out of the office visiting one of the projects in Texas. Won't be back for a week. In comes a purchase order request from Bill M______'s [the Project Coordinator] job. How will it get approved if Jack is out in the field?"
> **Employee:** "In that case I will call Bill or the superintendent on the job, verify the information and initial it myself. We have to get it approved before it can go into the system."

The employee took an initiative that was not supposed to happen because the company had already specified a means to fix that problem. The employee is supposed to get approval from a member of upper management for the Purchase Order.

Process for Labor Reporting

According to Robert E_____, the domain expert, each project is assigned a Project Coordinator whose responsibility it is, among other things, to coordinate and record the daily report provided by the Superintendent with the weekly time sheets. This is shown in Figure F-1. The Project Coordinator is responsible for correctly filling in the time sheets to show what work activities each employee did during the day. Daily work logs are kept on a Monday through Sunday basis, although it is rare that work occurs on weekends.

On Mondays the Project Coordinator will fax or send to the office the weekly time sheets with all other paperwork generated from the project. The weekly time sheets are sorted out by project by a specially designated Payroll Clerk in the accounting office. The Payroll Clerk manually runs a quick check of each time sheet to ensure that all information provided (e.g., job activity codes, employee codes and names) is correct. In case of missing information the Payroll Clerk is required to call the Project Coordinator on site and get the missing information.

Once all of a Project Manager's jobs have been examined for correctness by the Payroll Clerk, they are provided to the Project Manager for review. The Project Manager is supposed to check the Payroll Clerk's work to make sure that activity codes assigned to the project are correct.

Each Project Manager is also to approve the weekly log as a check that the company is actually getting the work it is paying for. The third reason provided for Project Manager review and approval is for the Project Manager to acknowledge any new employees that may have been hired.

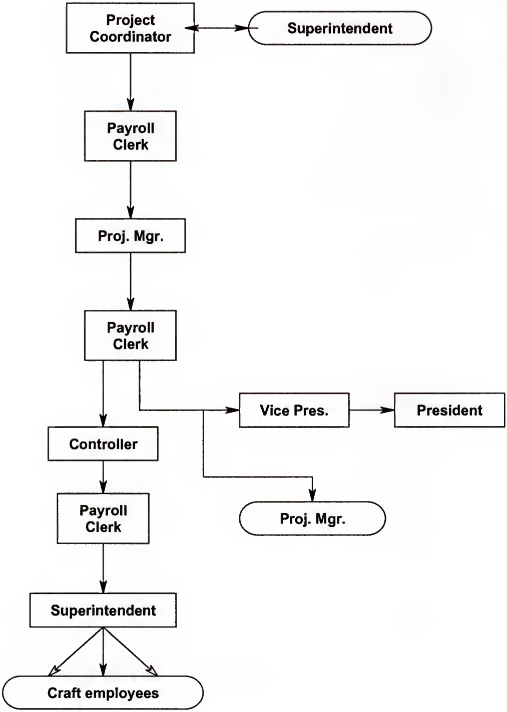


Figure F-1. Model of the "as-is" EDO Construction Company labor reporting process.

The Project Manager is responsible for approval of all new hires on his/her jobs. Customarily, new workers are put on by the Superintendent and start right away before receiving formal approval by the Project Manager. To get them working, the approval for these new employees is done in the office on the first time sheet turned in with their names on it. According to the Payroll Clerk very rarely, "only three times in my four years here," has a Project Manager not just signed approval for hiring a new employee. Most Project Managers trust their superintendent's judgement and experience in terms of hiring new employees.

Once approval has been granted by the Project Manager, all of the time sheets are returned to the Payroll Clerk. The Payroll Clerk enters the weekly project time sheets into the mainframe using a dedicated terminal set up in the Payroll office for that purpose. The accounting software provides, in addition to printing checks and calculating tax withholding for employees, summary labor reports.

The summary labor reports are broken down into three categories. One is the total summary of payroll for all projects. This is a monthly report provided to the Vice President for Operations and to the President for review. The second type of summary report is by project. Each project manager is given a monthly summary report showing the total amount of money spent on their projects for the month. The third type of summary report produced is one for the estimating department. It is broken down by project and activity for use in developing historical data.

Employee checks are printed up alphabetically by last name and must be manually sorted by project by the two Payroll Clerks after review and signature stamp by the Controller. Each project's weekly payroll is delivered by overnight carrier to each project superintendent or Project Coordinator. Checks are distributed the Friday after the closing of the previous pay period.

"As-is" Process for Request for Payment

At EDO Construction Company the monthly request for payment process, shown in Figure F-2, requires close coordination between the field office position of the Project Coordinator and the Project Manager. The Project Coordinator is responsible for ensuring that the project schedule is current when it comes time for billing the client. According to Robert E_____, because some of the projects the firm builds receive either state or federal funding, schedule management is crucial when it comes time for monthly requests for payment because typically this is required to be submitted with the pay request.

Each Project Manager is responsible for actually developing the monthly request for payment to the owner for their projects. Typically, subcontractors on the project will send their monthly draw requests to the Accounts Payable department of EDO Construction. Additionally, the Accounts Payable department within the Accounting office will have sorted out vendor billings for purchases on materials received at the project site during the month. It is the Project Manager's responsibility to go through these two sources of billing information with the schedule from the Project Coordinator and manually write the monthly invoice to the owner. The draft copies of the monthly invoice to owner are turned over to the Accounting Department for typing and entry into

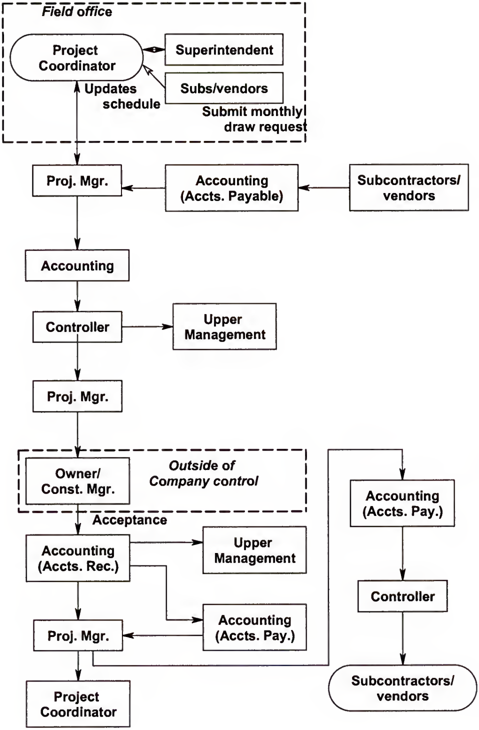


Figure F-2. Model of the "as-is" EDO Construction Company request for payment process.

the company mainframe and accounting software program. Under normal conditions this process takes about five days. Particularly large projects may require more time, but this is unusual.

The Accounting Department, after entry into the company mainframe, will produce cash flow projections for the firm and updated income statements. These are turned over to upper management (e.g., Vice President for Operations, Business Development, Project Management Director, and President) for review and analysis. The typed copies of the monthly invoice to owner are typically produced on American Institute of Architect's (AIA) form G-702, "Application for Payment," or the owner's own standard request for payment form if it is different from the AIA form.

Upon completion of the typing, all the requests for payment are given to the EDO Controller for review and signature. Once that step is completed, the Controller gives the copies of the monthly "invoice to the owner" to each Project Manager to review the billing statement one last time before sending them out. Each Project Manager is responsible for preparing any documentation required to back up a payment request, if any, in addition to checking the pay request. Where the Owner has contracted with a private outside construction management firm, the Project Manager is to arrange for an updated schedule.

Payment by the owner initiates two actions in the Accounts Receivable Department. First, they will notify upper management of the amount of requested payment by completing a form and making a copy of the check. Secondly, the Accounts Receivable section of the Accounting Department will notify the Project Manager and Accounts Payable that payment has been received on a particular project.

Accounts Payable clerks will prepare a list of subcontractors and vendors invoices they are prepared to pay on a given project. This is reviewed by the Project Manager who is responsible for approval or modification of the pay requests. Once approval of payments has been given, the accounts payable department will run checks for the approved amounts. These must be reviewed and signed by the Controller before mailing. Concurrent to the accounts payable section of accounting completing their run of checks for subcontractors and vendors, the Project Manager notifies the Project Coordinator of approved payments in case of conflicts at the project site.

"As-is" Process for Change Orders

Because of the rapidly changing conditions and incomplete design in hospital construction (as many as 30 change orders a day may be requested), EDO Construction must keep close watch on change order requests. Furthermore, according to the domain expert, RE, the company prides itself on "billing aggressively to make sure we are getting our money and the owner what they want." To keep up on the rapid pace of change orders, EDO Construction starts change order initiation by logging all requests in at the project worksite with the Project Coordinator. As shown in Figure F-3, even requests from the owner or architect, which customarily are sent to the Project Manager, are sent to the Project Coordinator to log and get pricing information.

Because of the high volume of change orders, the firm has set a goal for turnaround for a change order request of three days from day of inquiry. What this means is that if the architect of record requests a change in the project on a Monday, by Thursday morning EDO construction is able to give the Architect and the Owner or Owner's representative a request for a change order for the issue in question. The Project Coordinator has complete responsibility in this process to make sure the Change Order is fully written up in scope, priced, logged and sent to the Owner for approval. It should be noted that the three day turnaround on requests is only a goal and, depending upon the complexity of the change, may take several weeks for approval. This is dependent upon the client's process for approvals.

The researcher was provided several examples of both normal and longer term Change Order requests. A quick change order may be generated from the need to relocate the position of some doors or a desire to change the color of the chair/hand rail along the walls. A longer termed example provided was the change of an air filtration device for an operating surgery which took three weeks for calculating the cost of the new equipment, removal of the existing unit, extra wiring, etc.

Change orders which are rejected, on the basis of price or work scope, are reexamined by the Project Manager and Project Coordinator to see if the change order can be re-worked for approval by the Architect and the Owner. The Project Manager is the point of contact for all Change Order requests and Change Orders going in and out of the firm even though his/her role in development is minimal.

Once a Change Order has been accepted, as shown in Figure F-3, the Project Manager will log the acceptance in the Change Order log maintained in the office and fax a copy to the Project Coordinator to update the jobsite log. The Project Manager will also adjust the contract amounts for the appropriate subcontractors and vendors affected by the Change Order. When necessary, the Project Manager will manually write and issue new purchase orders or subcontractor change orders. The new purchase orders or subcontractor change orders are given to a designated clerk in accounting for typing.

The Accounting Department, in addition to handling all of the typing of purchase orders and change orders, also adjusts the contracts of the subcontractors involved. After typing, each purchase order or subcontract is reviewed and signed by the firm's controller. Once the signed copies of the change orders are received from the subcontractor, the Accounting Department clerks adjust the project budgets on the company's mainframe to reflect the new budget.

The Accounting Department gives all of the signed change orders back to the Project Manager. It is the responsibility of the Project Manager to verify that the scope of work is correct and to send the approved Change Orders out to the subcontractors or vendors. Furthermore, the Project Manager will make two sets of copies. One set is placed in the main office copy of the project files, and one set is sent to the project office for the Project Coordinator to update his/her log and maintain the job site files.

The Project Coordinator is not only responsible for updating the project log, but also for notifying the Superintendent of all changes. The Project Coordinator has the further responsibility of purchasing the materials for the project under the new purchase orders that have been issued as a result of any approved change orders. Depending upon the scope of the changes approved, the Project Coordinator is required to revise the schedule for the project, but according to one Project Manager who was formerly a Project Coordinator, "usually you just wait till there is a real reason to change the

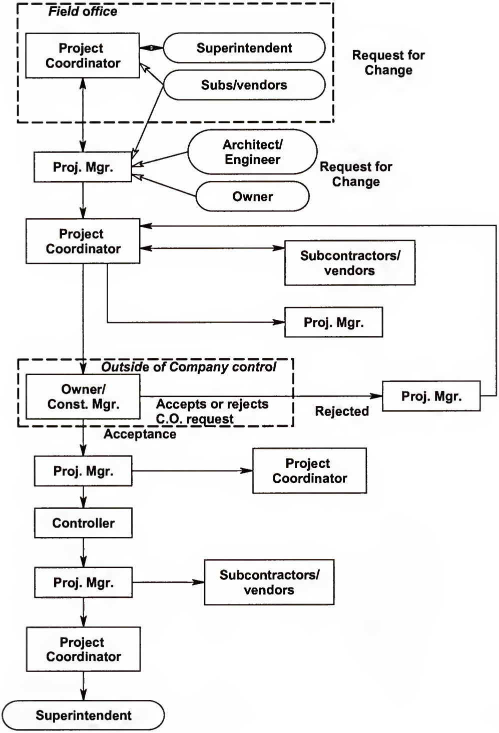


Figure F-3. Model of the "as-is" EDO Construction Company change order request process.

schedule. Otherwise you'd go crazy trying to update it everyday." Normally, the schedule will be updated at the end of the month when the next draw request is prepared.

APPENDIX G
CASE STUDY OF ABC CONSTRUCTION

Introduction

This firm, located in the Southeastern US, is a large General Contractor doing over approximately $200 million plus in business. The three processes examined and modeled as part of this research were labor payroll, payment requests to the owner, and change order requests. The completed "as-is" process models are shown as Figures G-1, G-2, and G-3 respectively. To protect the identity of the firm, the state its located in has not been discussed.

Roughly 60 percent of ABC's work is negotiated private work with the remaining amount publicly bid, non-government work. On most of its contract work, ABC is responsible for the structural element of the construction project as well as general supervision of other areas of the work. The amount of the workforce on a project that is ABC employees may vary from a superintendent and a small field crew of 5 or 6 to a labor force of one hundred or more.

The company maintains several field offices outside of their home state; these act as independent firms which maintain their own client base and accounting systems. None of these satellite offices were investigated as a part of this research. Instead, all information was gathered at the ABC's head office with the help of the Domain Expert, "Cory T_____," Vice President in Charge of Construction Operations, and from headquarters staff personnel. All of the satellite offices have their own procedures in place that are supposed to mirror the headquarters.

Level of Computer Use

Compared to other firms studied as part of this research, this firm is very sophisticated in terms of their use of computers and networking systems. The company has developed internally its own cost control and project management tracking software for managing projects, including the use of standardized forms which are used extensively by project management, field superintendents, and upper management. The firm's project management software is networked, and accessible from the field offices. All employees, including field superintendents, are on the network and training is provided for its use. Furthermore, clients and vendors do have dial-up access capability to the network.

The company uses the groupware applications of e-mail and electronic white boards. However, these systems had been in place for only slightly more than a year at the time of this interview and were still not being used extensively according to Cory

T_____. The company has developed its own spreadsheets templates for tracking labor costs. The firm has its own software development/computer administrative staff of one who writes programs or can build computers for the other members of the firm as needed.

Policies and Procedures

Processes and procedures within the firm are detailed, but consist of a paper based system that requires a system of manual checkoffs. Each satellite office utilizes the same process and procedures to ensure standardization between offices. The firm does have a policies and procedures manual, but at the time of this investigation, it was under revision as the firm was performing a self analysis of its operations in an attempt to ensure that the procedures were completely standardized as well as comprehensive enough to cover all areas of concern, such as how to perform roofing inspections or conduct meetings with clients.

Process for Labor Payroll

For ABC company the process of Labor payroll and reporting, shown in Figure G-1, starts in the field with raw data (e.g., hours worked and cost code information for specific job activities) collected by the field superintendent. Depending upon the size of the project, this data may be collected on a daily basis by crew foreman and then turned over to the superintendent for inclusion on a weekly time sheet that is either faxed or delivered to the office by an employee. One superintendent, queried about the time it takes him to complete the weekly payroll log with an example of a 10 person working crew, indicated that it took him "roughly twenty to thirty minutes" depending upon the number of different work activity classifications that were used.

Apparently, it is not uncommon for the superintendent to group workers together under a common activity regardless of what work they had actually performed that day. This procedure speeds up the labor reporting process which is usually completed at the end of the day. However, this approach will cause inaccuracies in collecting historic data for use in future estimates and labor burden calculations. The model for the labor payroll process is shown in Figure G-1.

The weekly labor reports are either faxed or taken by the superintendent or a "runner" to the office for entry into the payroll system. Once all of the weekly labor reporting sheets are collected in the office they are manually job costed by a clerk in the payroll section of the accounting department before being keypunched into the computer by a separate individual.

After all payroll information has been entered into the accounting software the accounting department produces a "balance report." The balance report is used by the payroll department to manually check against the hours recorded on the weekly time sheets. If, for example, a person is recorded as having worked on a holiday or more hours during the week than the rest of the crew, the balance report is designed to catch this. The balance report is checked by the same payroll clerk that codes in the labor information.

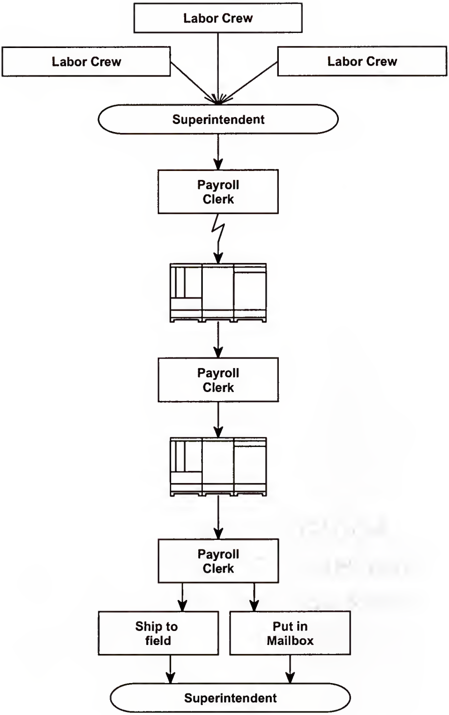


Figure G-1. Model of the “as-is” ABC Construction Company labor payroll process.

Upon completion of the balance report verification, and assuming there are no changes, the payroll is generated with the computer program automatically withholding any state and local taxes. The withholding rates are keyed in at the beginning of a job. Once the computer program has calculated withholding of taxes, it generates checks alphabetically. These are checked manually one last time to ensure that the each person is paid for the correct amount of hours worked. After all of the checks have been checked for correct checked for the correct amount of hours, they are manually sorted by job each employee is assigned to by the payroll clerk. At the same time, a new time sheet is generated by the computer program for each job.

Once the payroll clerk has manually sorted the checks, he/she either prepares them to be shipped to the jobsite by overnight carrier or the checks are put into the mailboxes of the superintendents for them to pick up.

Labor updates for projects are run every two weeks with review copies uploaded to the network for review by the project manager and upper management. One hard copy of the labor update is provided to the field for use by the field

Process of Pay Request to Owner

Figure G-2 shows the model of the existing process for ABC's monthly Pay Request by Owner for its jobs. At the beginning of all jobs by the firm, a schedule of values is developed by Project Managers for their specific jobs. This schedule of values is entered into the existing computer system by the billing clerk. As the billing period for the month comes up, usually the 25th depending upon the client, the Project Manager will produce an updated schedule of values report. The schedule of values is depends upon work completed in the field. The Project Manager collects the field information either through daily field reports or by calling his/her project superintendents. The actual process of verifying field data varied for each project manager as the two that were interviewed gave conflicting testimony as to how this information was collected.

The updated report is typed into the system by the billing clerk and a proofing copy is provided to the Project Manager for approval and any changes. If the proofing copy is accepted, the billing clerk will type up a American Institute of Architect's (AIA) form G-702 "Application for Payment" or the owner's own standard request for payment form if it is different from the AIA form. This form is returned to the project manger for verification. The Project Manager is responsible for *manually* writing in the numbers on the monthly pay request to owner as shown in the process model, Figure G-2.

Once all the numbers have been put together for the payment request, the manually written copy by the Project Manager will be key punched into an electronic spreadsheet by the billing clerk and percentages will be calculated. The electronic copy will be printed out and provided to the Project Manager for verification. Once this has been verified, a letter to the project Architect requesting payment will be written by the billing clerk.

The letter and the approved AIA document G-702 will be signed by the Project Manager and notarized by one of the notaries in the accounting department. The Comptroller will also sign as an officer of the company. In the absence of the Controller, the Company President or several others have the legal ability to sign as officers of the

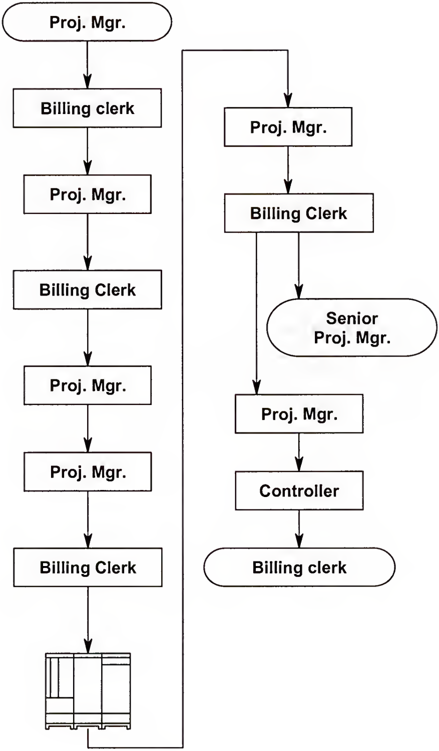


Figure G-2. Model of the "as-is" ABC Construction Company request for payment to owner process.

company. Finally, the billing clerk will prepare an envelope and send all of the material to the architect or owner's representative. According to several sources interviewed, this process takes about 5 working days from when the billing clerk first enters information into the system until the billing clerk is putting all of the back up material and the Pay Request forms into the envelopes for shipment to the architect or owner's representative.

Process of Change Order Request

The start of any change order request may come from a variety of sources including the GC, subcontractors, the architect or even the owner. As shown in Figure G-3, under the "As-is" Change Order request process model, any requested Change Order is logged into a file kept for each job by the Project Manager. Once a Change Order has been requested and logged in, the information regarding the Change Order may be requested by the Project Manager. The information may take several forms (e.g., estimate for new work, invoices for materials, payroll logs or daily reports) to substantiate the claim for a Change Order and may come from several sources (e.g., subs, suppliers, estimating department).

Once all the information has been gathered together the Project Manager will develop a Change Order proposal. The actual size and format of the Change Order depend upon the particular client involved. It was told to this researcher that some owner's representatives do not wish to be "nickel and dimed to death for each Change Order." Instead, these clients want a minimum of Change Orders, but are willing to lump a number of disparate items together to keep requests to their firm's budget officers to a minimum. Other clients "want all Change Orders to be fully backed up with all applicable paperwork on each item." It should be noted, as shown in Figure G-3, the decision to accept or reject Change Orders, while a part of the process, is not under ABC company control in terms of how long it will take for a decision to be made. Depending upon the client, this can take several weeks.

If a Change Order request has been approved by the owner, it is returned to the company, and the Project Manager is responsible for obtaining a company officer to sign off and logging it into the system as approved. The Project Manager sends out field notices or Change Orders to the relevent subcontractors and vendors and updates their contracts or purchase orders accordingly.

Change Orders which are not approved are logged into the system accordingly. Once a month a report is generated for each project indicating the status of all Change Orders and is provided to the Senior Project Manager for his review. Change Order requests that are outstanding for longer than thirty days are manually flagged by an Project Manager assistant for the Project Manager to follow up with the party involved.

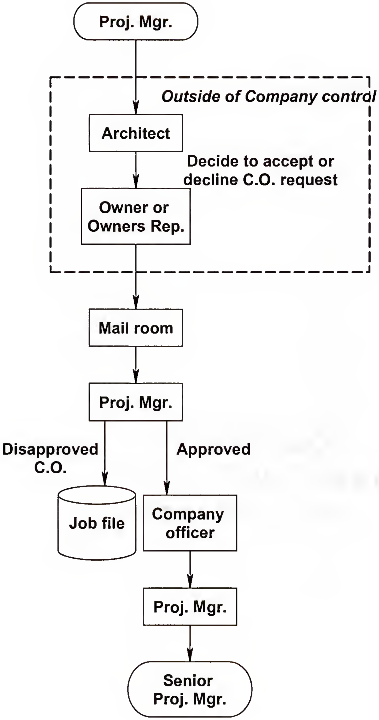


Figure G-3. Model of the "as-is" ABC Construction Company change order request process.

APPENDIX H
CASE STUDY OF THE XYZ BUILDING COMPANY

Introduction

The XYZ Building Company is the multi-million dollar American Construction division of a larger foreign owned and based construction company. The XYZ Building Company has several divisions and subsidiaries that have approximately 1.5 Billion annually in total construction contract work with the majority of it in Civil Construction projects (e.g., roads, dams, bridges). For this research only the General Construction division of XYZ Building Company was examined. This division of the firm reported doing 250 million dollars in General Contracting or construction management work. The projects built ranged from hospitals to academic structures (e.g., libraries, high schools, auditoriums).

The firm, while owned and controlled by a foreign concern, is allowed to freely pursue contracts throughout the United States and Canada. The XYZ Building Company General Construction division maintains three major offices across the county and seven regional offices in the US and Canada that either offer specialized services (e.g., engineering and architectural services) or to handle particular clients. The headquarters of the firm, located in the Midwest, was the primary point of contact for this research, but a satellite branch office in Georgia was also examined.

The processes studied and modeled as part of this case study were XYZ's process for labor reporting, request for payment to the owner, and change order requests. There were two domain experts for this particular case study. At the headquarters, interviews were conducted with a Regional Vice President of the firm, Bill D_____, and at the branch office a Project Manager, Wendy P_____.

Level of Computer Use

XYZ Building Company maintains its own information systems department that provides services to the entire firm regardless of division or subsidiary. The firm makes extensive use of e-mail, down to the level of the superintendents, and maintains a company intranet that is accessible to all regular employees. The company intranet is used for internal company correspondence and information flow and is not accessible to persons outside the firm.

At the time of this research the company was looking to develop a separate, but parallel, World Wide Web site for dissemination of project information and electronic bulletin boards. However, at the time of the research visit, this was still in the planning stage. This researcher was also told that one or two of the satellite offices that have been set up for specific clients have their own server systems that permit the client to access that particular office's systems.

Surprisingly, however, despite the common use of e-mail to communicate between the field and the home office, most processes remained paper based with a heavy reliance on faxes or paper copies required for backup. The reason provided for the use of paper and multiple verification checks of labor reporting was that in the mid to late 1980's the company experienced problems with fraudulent labor reporting from some lower level employees that apparently caused a severe financial crunch and several legal liability problems. Upper management expressed little interest in changing this safeguard in the system.

It was told to this researcher that the firm was looking into converting over to a paperless system utilizing Lotus Notes®, but not all of the division managers and members of upper management of the company had "bought into that idea." Additionally, it was remarked to this researcher that there is a fairly "high level of dissatisfaction or inability to change with our older superintendents when it comes to computers." According to the Domain Expert, Bill D_______, a Regional Vice President for the company, XYZ "will be completely on-line within five years" because "it will be necessary in order to stay competitive and our more computer sophisticated clients demand it."

The firm uses a commercially available project management software, Primavera's P3 for Windows®, for controlling its larger projects where required by contract, federally funded projects such as a Veterans Administration Hospital, for example. But the Domain Expert revealed that "for most projects we use SureTrack® or MS Project® [commercially available scheduling software] because these are easier for our guys and our clients to understand."

XYZ Building Company has developed its own document management software program, but it is a DOS based program. The domain expert, Bill D_______, claimed that the document management software currently used by the company "is excellent" and proceeded to give this researcher a demonstration of its use, but that opinion is not held by all as its use varies between project managers and offices. However, the second domain expert interviewed as part of this research, Wendy P______ mentioned, "it has a steep learning curve and is not user friendly. At all!"

The accounting software used by the company was developed in house by the parent company and is required for use by all branches of the firm. The concept behind this is that the financial data of the firm can then be easily accessed by the parent company for inclusion in financial statements prepared for the company owners.

Policies and Procedures

The firm, at the time of this research visit, was in the midst of preparing for auditing by outside consultants for ISO 9000 certification. The company provides and regularly updates a comprehensive policies and procedures manual that is designed to document all of the normal processes that occur in each of the offices. The firm has made extensive use of outside consultants as well as internal review to critically examine how it was currently performing management processes. The company's own internal review included the three processes of this research: payroll, requests for payment, and handling change orders.

Each new employee, regardless of position, is first introduced to the company by a two week training session at the company headquarters where they are provided a manual that documents their specific duties and responsibilities. According to Bill D_______, each new employee is lectured to about being sure things are done "according to the XYZ Building Construction Company philosophy" and provided his/her procedures manual. One employee queried about the manual stated,

> "at the beginning, when I first went to work here, I used it all of the time. It was filled with useful stuff on who to go ask about something and time management tips. Now that I have been here a couple of years I rarely look at the thing except to put in updates that are sent to me."

The XYZ Building Company domain expert, Bill D____, was unwilling to provide this researcher with a personal copy of the firm's procedures manual. This was explained as a desire on the part of the firm not to give away too much of their company secrets. However, Bill D____ did provide the researcher a room, a table and copies of the procedures manuals for Project Managers, Assistant Project Managers and Office Engineers in order to verify the validity of the research field notes taken during the interviews with company employees.

"As-is" Process for Labor Reporting

XYZ Building Company management attempts to better control its scarce labor forces by a multi-stage review process of labor payroll. The conceptual idea behind this process, shown in Figure H-1, is to allow quick readjustment on projects of the size of the field crews in order to better control the project's progress. The Office Engineer, located in the project trailer, is responsible for collecting the daily time sheet information and recording the work activities of the company's craft employees (welders, fitters, etc.) from the superintendents or foremen. Depending upon the size and complexity of the job, there may be a General Superintendent and two or three specialty superintendents (e.g., Steel erection, Mechanical and electrical, finish). Additionally, there may be several foreman responsible for running specific crews, particularly on projects with multiple buildings (e.g., an industrial park). The information collected on the time sheet is required to be faxed or otherwise transmitted to the Project Manager's office within 24 hours of the day completed. In the absence of the Project Manager the time sheets are to be faxed directly to the Division Manager for approval and review.

The Project Manager is responsible for updating the project schedules maintained in his or her office and generating labor force requirements projections for the future. The project manager is also responsible for maintaining a weekly log of activities completed; this log is then transmitted electronically to the Division Manager's office and the regional office for the Regional Vice President's review.

The Division Manager also reviews the weekly log of activities and the payroll log. He/she is responsible for taking the Project Manager's labor force requirements projections and balancing the crew levels by transferring or moving craftworkers from

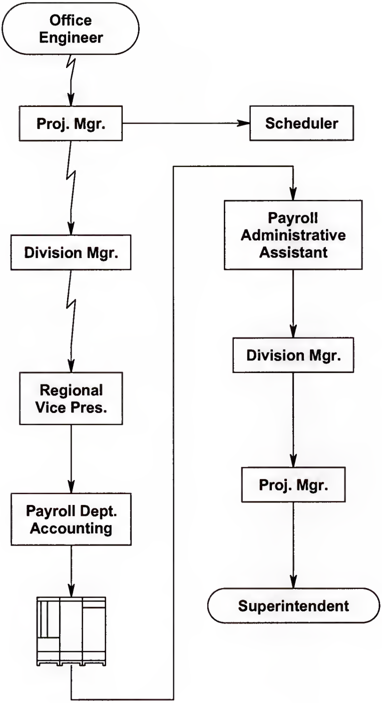


Figure H-1. Model of the "as-is" XYZ Construction Company labor reporting process.

one project to another. The company tries to keep as many of its craftworkers employed as possible by moving them from project to project, or even to another division within the larger holding company if necessary and whenever possible .

The Regional Vice President reviews and approves each of the weekly payroll logs for all projects within the division. Theoretically, this procedure offers better control of project costs by providing a second pair of eyes with the local project manager. It also provides a check in preventing labor fraud which the company had experienced back in the middle 1980's. The Regional Vice President passes on the approved labor hours time sheet to one of several Payroll Department accounting clerks for entry into the accounting system.

The Payroll Department in the Accounting office key punches in the information to the firm's accounting software package. The firm's own designed software program will calculate the withholdings on each check, produce a monthly status report for upper management, and sort out job cost information.

The monthly status report is sent to the Regional Vice Presidents and to the National Headquarters offices. Job cost information is printed out and sent to the Project Managers tracking costs on their projects and to the Estimating department for their use in future historical data.

Once printed, checks are turned over to a designated administrative assistant of the Payroll department. This person will separate out all of the checks manually for each project and for each Division Manager. Some cases have occurred in which the wrong checks were sent to the wrong division because of projects having the same name or owner, but were located in different geographical divisions. For example, a project labeled "Troy Motor Company Bloomington" may have gone to Bloomington, Indiana instead of Bloomington, Illinois. The parcels containing the checks are either picked up by the Division Managers or are shipped to them by overnight carrier.

The Division Manager is responsible for verifying that all of the checks, projects, and employees match. Any employees that have been transferred to another project are supposed to receive their checks at that new project location with all other employees. The Division Manager gives each of his/her Project Managers an envelope that contains the sorted checks for their project employees.

The Project Mangers are responsible for distribution of employee checks to each superintendent. If a superintendent is on vacation or otherwise unavailable the Project Manger is supposed to personally make sure that all employees receive their checks and sign for them. The Project Manager is also supposed to periodically hand out employee's payroll with the superintendents as a check, but verification of that actually occurring could not be independently confirmed by the researcher.

Payment Request to Owner Process

The monthly payment request to the owner process, as shown in Figure H-2, varies considerably from the process for labor reporting shown previously in Figure H-1. Because of the need to quickly generate the monthly pay request to the owner, the Division Manager is responsible for signing off as the XYZ Construction Company's official representative. Although not explicitly shown in the process model, the monthly

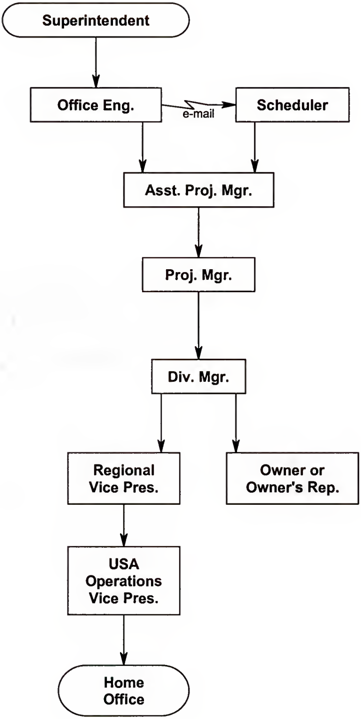


Figure H-2. Model of the "as-is" XYZ Construction Company payment request to owner process.

pay request process begins with the Assistant Project Manager, who generates a checklist of subcontractors activities and work activities XYZ Construction Company forces have participated in to prepare the monthly pay request to owner.

The Superintendent is responsible for verifying that all field work being billed by subcontractors or XYZ Construction forces has been completed or is nearly complete. Superintendents are responsible for reconciling this daily log with the weekly log compiled by the Office Engineer to ensure that both are up to date and correctly show the work in progress. The Office Engineer and the Superintendent are both charged with ensuring that the weekly field data is provided to the Scheduling department so that job progress is recorded as it happens.

The Office Engineer is responsible for contacting and collecting all subcontractors' monthly pay requests invoices and reconciling these with the daily field reports from the Superintendent, the weekly field log, and providing this information to the Assistant Project Manager.

The designated Scheduler from the Scheduling department is required to update project schedules on a weekly basis with the input of the Superintendent and Office Engineer. At the appropriate time for billing the owner of the project called for in the contract (typically the 25th of the month), the Scheduler is to produce a completely updated project schedule showing work completed, work completed since the last billing, and work scheduled for completion during the next billing period if any. This information is provided to the Assistant Project Manager for each project he or she is responsible for.

The Assistant Project Manager is, according to several sources, the linchpin that is responsible for developing the pay request and bringing together the separate elements of the subcontractor pay requests, vendor invoices, and developed schedules. Each Project Manager within the firm may have several Assistant Project Managers assigned as this is seen as by the firm as a necessary training and learning position for all employees being groomed for upper management.

Each Assistant Project Manager is responsible for projecting the amount of work to be completed before the end of the billing period that will be included in that month's "draw" request. The Assistant Project Manager is also charged with ensuring that the pay requests from the subcontractors match up with the schedule and weekly field reports in terms of work completed and being billed for.

The Project Manager reviews the pay request put together by the Assistant Project Manager assigned to the project and converts the pay request, if necessary, to the particular project owner's format if the project owner does not use the American Institute of Architects Form, G107 Request for Payment. The Project Manager is also responsible for calculating the retainage percentage amount that the owner will hold back on the project for each activity. It was explained by the Domain Expert, Bill D_______, that very often this step will also be completed by the Assistant Project Manager as part of his/her training, but that it was the responsibility of the Project Manager to verify that all of the calculations were correct and that the proper forms were produced. These forms are given to the Division Manager.

The Division Manager is the person that is ultimately responsible for all work completed within a particular regional district office. The Division Manager signs all

Payment Requests to the Owner as the official company representative. The Division Manager is responsible for making and forwarding copies of all pay requests to the Regional Vice President and sending the originals of the Payment Request forms to the Project Owner or the Owner's Representative for review and payment.

The Regional Vice President is responsible for determining the amount of XYZ Construction company financial support required in terms of cash flow and the level of credit required for the entire Region. Each Regional Vice President is also responsible for monitoring the amount of work under contract to ensure that the Region is under its required bonding capacity for the firm. A secondary responsibility of the Regional Vice President is to monitor the type of projects being completed in terms of their profitability and amount of projects being completed.

The management of the firm's bonding capacity and project profitability are two of the most closely watched factors for upper management as this apparently has been a problem in the past. Each Regional Vice President is required to meet monthly with the national Vice President for Operations to review bonding capacity needs and individual project profitability. The national Vice President for Operations office is responsible for developing monthly and quarterly financial statements for the overseas home office based on the monthly pay requests from each project.

Change Order Request Process

The standard process for generating the change order request at XYZ Construction Company is similar to many construction firms that perform much of their own work. Typically a change in the project, because of a conflict between drawings, additional work requested or some other reason, forces additional costs to be borne by the General Contractor that were not accounted for in the original estimate. At XYZ Construction Company, the "Office Engineer," a position maintained in the field office jobsite trailer, is responsible for initiating the Change Order Request Process, as shown in Figure 3. Even when the Project Manager may be contacted directly for a change order from a subcontractor or the owner's representative on a project, this information will be kicked back to the Office Engineer in the field to write up on a company form exactly what work is required, who is requesting it, why, etc. The Office Engineer is responsible for developing the justification as to why a change order is required on a project.

All of the client examples or anecdotes of change orders provided to the researcher during the course of the process interviews basically repeated that for any change in the work, a change order request was to be made and documented. Change orders were not to be grouped together, but were to deal only with one issue at a time in order to ensure that all costs were being properly tracked and accounted for if claims for liquidated damages or project delay were required. Liquidated damages is a penalty required to be paid by the contractor to the owner if the projection completion is not achieved by the date set in the contract. Virtually all contracts, signed by XYZ Construction Company, have some type of liquidated damages clause.

Once the Office Engineer has completed the Change Order request form he or she will forward this to the Assistant Project Manager. The Assistant Project Manager maintains a computerized log of all change orders requested. Once a Change Order

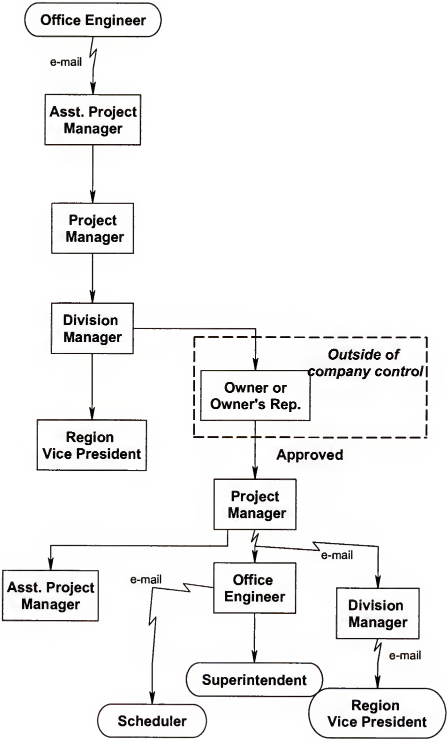


Figure H-3. Model of the "as-is" XYZ Construction Company change order request process.

request has been received, the Assistant Project Manager will log the request and give it a "tracking" number. It is the Assistant Project Manager's responsibility to get cost information from Subcontractors that will be impacted by the Change Order. It is also the responsibility of the Assistant Project Manager to estimate what XYZ Construction Company's forces will be required and obtain prices from Vendors if required. The Assistant Project Manager is also charged with determining what schedule changes, if any, will be required.

The Project Manager is charged with reviewing the Assistant Project Manager's work. Typically, he will review the proposed Change Order by calculating the overhead and profit involved, but it was hinted at that often the Project Manager will hand this responsibility off to Assistant Project Manager to do this also. Regardless, the Project Manager is supposed to have reviewed the proposed Change Order and initialed it before forwarding it to the Division Manager for review and approval.

Division Managers at XYZ Construction Company are responsible for representing the company in all contractual matters that involve project "work." As "legal agents" for the firm, they have both the authority and responsibility of binding the firm to work commitments or contracts. According to Bill D_______, this is not because they do not trust Office Engineers, Assistant Project Managers, or Project Mangers, but because of the problems from lax labor controls which allowed fraudulent reporting in the mid 80's.

Division Managers are required to forward on to the Regional Office Vice President a copy of the requested change order. The Regional Vice Presidents, technically, do not have veto power over Change Order proposals, but provide these individuals with the ability to make changes in the financial statements and forecast projections. It told to the researcher that reviewing the change order requests also provides the Regional Vice Presidents with a "better 'feel' for how the work is proceeding on projects. That is important in a large company like this that is spread out so far."

Division Managers, once they have signed the requested change order letter, are charged with the responsibility of getting it to the project Owner's representative. According to Bill D_______, very typically this a construction management firm that has a contract with the owner to provide the owner with management expertise in the construction area. This is a common approach for many school districts and hospitals with large building programs.

If the owner has agreed to the Change Order, it is typically returned directly to the Project Manager for the project. The Project Manager will formally notify all subcontractors and revise or issue new purchase orders to vendors affected by the signed change order. The Division Manager will receive a copy and is responsible for revising the project budget accordingly. The Division Manager will also notify the Regional Vice President, but this is merely for purposes of updating the current contract under bond information for the firm's surety company.

With approval or denial of the Change Order the Project Manger will provide a copy to the Office Engineer who is responsible for revising the schedule, if required, and coordinating changes with subcontractors and the XYZ Construction Company superintendent on the project. The Assistant Project Manager will also be notified by the

Project Manager. The Assistant Project Manager is responsible for updating the Change Order log so that it represents the most recent changes to the contract. The document software program developed by XYZ Construction Company is designed to provide an automatic "tickler" file to the Assistant Project Manager every 10 days so that Change Orders in the process that have not been approved by the owner can be followed up.

APPENDIX I
CASE STUDY OF Q AND Q CONSTRUCTION, INC.

Introduction

Q and Q Construction is a small, 35 - 40 million dollar in volume, privately owned, Florida based contracting firm. Primarily this firm contracts out all work to subcontractors and maintains only supervisory control over its projects.

The firm is a closely held one with the owner and President, Jay Q_____, very much involved in the operations of the company. One hundred percent of their work is contract bid work with various US Government agencies (e.g., Corps of Engineers, Department of the Navy). The firm does not bid in the commercial marketplace.

The company provides only supervision on projects and all labor is subcontracted, which is not uncommon in the construction industry. Consequently, only the request for payment and change order processes within the firm have been modeled as part of this case study. The Domain Expert for the development of the case study is the President Jay Q____.

Level of Computer Use

Q and Q is a networked firm which utilizes e-mail for a communication medium with its clients' agents. At the time of this investigation, however, this system had been in place for less than one year. Training was being provided by the firm so that everyone would know how to use the system, and top management encouraged its use. An off the shelf system (e.g., Eudora) was being utilized by the firm for e-mail delivery.

The firm does make extensive use of specialized software such as Primavera's P3® for Project scheduling and Filemaker® for databases, and provides training for their use. Jay Q_____, the domain expert, indicated that all Project managers and superintendents are trained in the use of P3® and can use it to manage their projects. However, during the observational visit by this researcher, it was noted that the primary user of P3® was the company scheduler and project managers and superintendents went to him for updating, reporting or making other changes to their project schedules.

The company does not use any type of specialized document management software (e.g., Expedition®, Open Plan®), but does use a database program for tasks such as document tracking, invoice tracing, and job costing, among other things. Q and Q does keep an extensive electronic file document system with many of the forms created in Excel®. However, because of the lack of ability by government agencies to access Excel®, most of the forms are printed and completed manually by the project managers or superintendents.

Because of some problems that occurred years ago, Jay Q_____ feels it necessary to personally review, inspects and distribute internally to the Project Managers all correspondence, billings, transmittals, etc. that are received or that are mailed out by the firm. This is reflected in the process flow models presented.

Policies and Procedures

There is no formal, written polices and procedures manual for the firm. There is an employee manual that describes the duties of each employee's position, but it does not go into specific detail oabout handling specific procedures. Instead, the firm relies mostly on each new employee learning mostly from on-the-job training.

Process for Labor Payroll

As was discussed in the Introduction to this case study, Q and Q Construction company does not have any of its own craft workers and does not hire any. All work is subcontracted out. Q and Q Superintendents are salaried employees or, in some cases contracted employees, and do not maintain a separate record of their work activities. Consequently, there is no Labor Payroll Process model for this firm.

Process of Pay Request to Owner

Figure I-1 shows the model of the existing process for Q and Q 's monthly pay request to the Owner. Each Superintendent is responsible for writing daily and weekly reports of activities on his/her job sites. These reports are forwarded to the company scheduler either by fax, telephone, or Federal Express® packet. The Scheduler compares the reports to the job schedules and update the schedule if necessary. Superintendents are responsible for notifying the superintendents of the subcontractors on projects when the subcontractors are supposed to provide a bill for work. This is done rather informally as it is assumed by Q and Q company management that the subcontractors are closely monitoring their own workforces for billing purposes.

When a pay request is required (i.e., enough work has been completed on a project for billing purposes), the Scheduler produces a completed updated schedule and verbally notifies the administrative assistant in the Accounting department. As part of most Federal government contracts, a current updated schedule must be submitted at the time of the pay request.

As shown in Figure I-1, the administrative assistant will set up pay vouchers for each sub contractor on the job. The pay voucher is an internally developed company form that indicates the contract amount, scope of work, any Change Orders approved, payments to date on a specific job to a specific subcontractor. The Project Manager manually puts the pay vouchers into files set up for each job for review. Additionally, a copy of the monthly updated schedule for each job will be put into the job files.

Each Project Manager is responsible for reviewing the pay vouchers and updated schedule for his/her own projects. If there are any changes, the Project Manager is responsible for making those corrections. After review by the Project Manager, all files are returned to the Administrative Assistant in Accounting for making any changes.

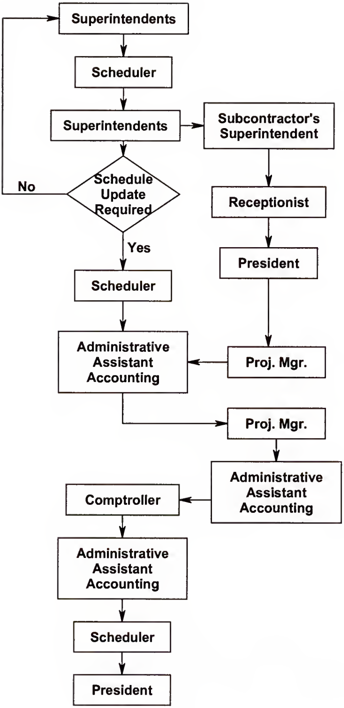


Figure I-1. Model of the "as-is" Q and Q Construction Inc., request for payment process.

Once all changes have been made by the Administrative Assistant, all of the job files are turned over to the company Comptroller who verifies pay requests or approves all changes to pay requests to the owner. This verified information is returned to the administrative assistant who will make copies of everything and put them into the permanent job files. The administrative assistant will also give a copy of the pay requests to the Scheduler.

It is the Scheduler's job to calculate retainage for each job and to generate the actual invoice to owner. Because of the different departments or administrative units of the Federal government that Q and Q Construction may deal with, there are a plethora of regulations regarding retainage and the particular forms that are required to be used as the monthly pay request form. It was told to this researcher that the other reason why the scheduler is responsible for generating the invoice to the owner is to ensure that all of the work being billed for matches correctly to the dates provided on the schedule.

The President receives all of the pay requests from the Scheduler, reviews and signs them himself before sending them out to the responsible "contracting officer" at the government agency the work is under contract to. He feels this is necessary to ensure that he "has a good grasp" of where the money is going and how much is coming in.

Change Order Process

Because of the nature of the work that Q and Q Construction performs (supervising governmental building construction projects), there is a significant amount of change orders that are generated on any given project. The change order process at Q and Q Construction, modeled in Figure I-2, is very involved and rather lengthy. Approval on a change order can take "up to two months," but the more typical length of time is five weeks. The reason for the long approval period is because of the need for outside information, from subcontractors and their vendors, or approval from the government contracting officer. Typically, it is the latter that is the cause of delay for approvals.

Almost all change order requests are mailed to the office of Q and Q directly. This policy is written in the contracts of all the Q and Q 's subcontractors and is required in many of the government contracting agencies that Q and Q. works for. This process ensures that a "paper trail" is created that clearly shows who requested the change order, why they requested it, and very importantly when it was requested. According to the Vice President of the company, there have been some problems in the past about getting change orders approved in a timely manner or problems closing some projects and getting paid because of outstanding change orders. By having all requests for change orders in writing and delivered directly to the main office, and not to a Superintendent, the company minimizes this problem and provides for a legal backup in case extra money is requested because of delay in Change Order approval.

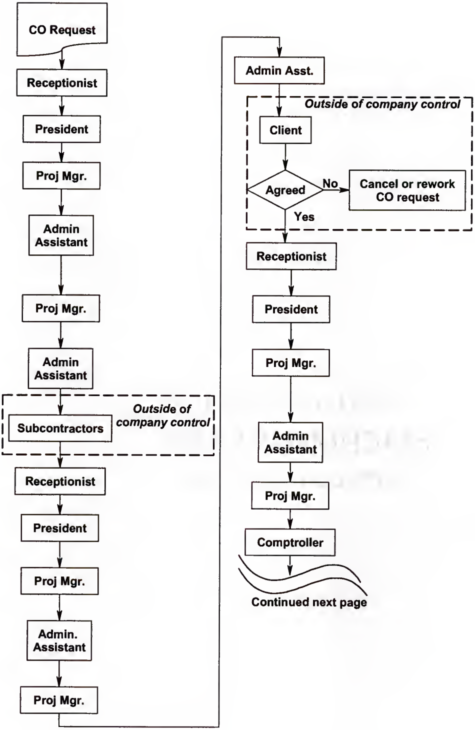


Figure I-2. Model of the "as-is" Q and Q Construction Company, Inc., payment request to owner process.

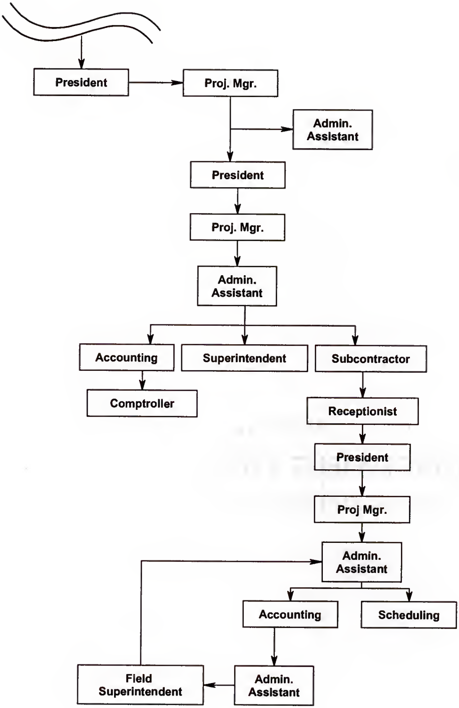


Figure I-2--continued

All mail, regardless of source, is given to the President for sorting. The President determines which Project Manager is handling a particular job when a change order request is received. The Project Manager will give the Change Order request to his or her administrative assistant to update that particular project's Change Order request log and assign a Cost Proposal number. There is an administrative assistant (or A.A.) assigned to each Project Manager. Administrative assistants at Q and Q Construction, Inc. act as the equivalent to an Assistant Project Manager in other construction companies although these people do not necessarily have degrees in Building Construction or Construction Management.

Once a cost proposal number has been assigned and initialed by the Project Manager, it is the responsibility of the Administrative Assistant to gather the relevant cost and back-up information from subcontractors impacted by the Change Order. The subcontractors affected are identified by the Project Manager before returning the Change Order proposal to the Administrative Assistant for pricing. The Administrative Assistant mails a request for information to each subcontractor the Project Manager has identified will need to provide price information.

Pricing information from subcontractors, as shown in Figure I-2, is received in the mail or by specialty carrier (e.g., Federal Express®) by the receptionist. All of this information is turned over to the President, who sorts it out and manually distributes the information to the requisite Project Manager.

It was told to this researcher that each Project Manager usually just turns this information over to his/her Administrative Assistant, who is responsible for preparing back up files for each Change Order request. The back up files contain copies of all correspondence between the Project Manger, Contracting Officer (or the Owner's representative), Architect of record, the project design engineers and subcontractors. Once all the back-up information from subcontractors has been received, the file is turned over to the Project Manager for review and pricing.

The Project Manager reviews the file to ensure that all subcontract information and backup (e.g., invoices, time sheets, estimates for new work) are enclosed. The Project Manger will manually put together a completed proposed Change Order using the specific form or format required by the contracting agency for that particular project. According to the Domain Expert, Jay Q _____, this can vary quite widely from agency to agency. The Project Manager is also responsible for calculating the amount of overhead and profit by contract that Q and Q may charge for an approved Change Order. This completed file is returned to the administrative assistant.

The administrative assistant checks over all of the numbers in the Change Order proposal to make sure that they are correct and updates the Change Order log to indicate that the Change Order request has been sent to the contracting agency. There was some disagreement here in discussions between the Domain Expert and the Administrative Assistants and others interviewed as part of this research. According to Jay Q_____, before the Change Order request is sent out, he, as President of the company, is supposed to review it. However, several of the Administrative Assistants and one of the Project Managers interviewed said that this was not the usual pattern except on particularly troublesome projects or where "large amounts of dollars were involved." "Large amounts of dollars" was not clearly explained, but when given the example of

"$50,000 or more," that was considered to be large enough to warrant the attention of the President. Presumably then, Change Orders for less than $50,000 dollars, unless on contentious contracts, are not examined by the President.

After the contracting agency has made a decision on the Change Order, it is mailed to the company for implementation. As discussed earlier, all mail is collected, reviewed, sorted and distributed to each Project Manager by the company President.

Each Project Manager is responsible for reviewing the contract information and change order as approved. The Project Manager will manually draw up a Change Order for each subcontractor affected by the approved Change Order from the owner and change his/her contract amounts accordingly. This information is provided to the Project Manager's administrative assistant for typing up all of the paper work.

After all of the change orders to subcontractors have been typed and approved by the Project Manager, they are given to the Comptroller for budget review. After budget review by the Comptroller, the subcontractor change orders are given to the President for review and approval. It should be noted that at this stage, the President is not actually signing approval to the Change Order, but merely reviewing the Change Orders to be issued so that he is kept informed as to what is happening on the job.

Once the President has completed review of the Change Orders, they are returned to the Project Manager who is responsible for writing the final subcontractor agreement and Change Order incorporating any changes required by the President or Comptroller. At the same time, copies of the final Contracting Agency's Change order to Q and Q Construction are filed by the Administrative Assistant and the Change Order log is updated.

The completed final subcontractor's Change Orders are provided to the President to sign and returned to the Project Manger. The Administrative Assistant makes copies of the signed Change Orders for the subcontractors and handles the distribution of these throughout the company, mails a copy in triplicate to each required subcontractor, and puts the original signed copy in the job files.

Within the Accounting department the Comptroller will input the changes into the system software and prepare to modify the project budget for each subcontractor's account. At Q and Q Construction, only the President and the Comptroller have software access rights to modify the project budgets.

Once each subcontractor has executed the Change Order (e.g., signed it) it is returned to Q and Q. As described earlier, copies of the Change Order are reviewed and distributed by the President to the Project Manager involved. The Administrative Assistant for that Project Manager is responsible for distribution of the signed copies to Accounting and to the Scheduler. The Accounting department updates the subcontract and signs off on their copy that this process has been completed. The Scheduler will modify or update the schedule to reflect any changes to the project that may have been approved by the contracting agency and file his or her signed copy in the Scheduler's job file for the project.

The Administrative Assistant will also notify the field superintendent and provide him with a copy of the signed Change Order. The field Superintendent is responsible for verification of changes to the work as required.

APPENDIX J
CASE STUDY OF BBB CONSTRUCTION CORP.

Introduction

BBB Construction Corp is a small, privately held construction company which does approximately 30 - 40 million dollars per year in volume. The management of the firm is unique in that it is made up of four equal partners, one of whom serves as the President. Each partner is permitted wide latitude in terms of what projects he/she may pursue, but each partner tends to specialize in a particular area of construction (e.g, tenant build-outs in Malls, restaurants). The partners pride themselves on maintaining a very entrepreneurial or relaxed nature of office controls. According to the domain expert and President, Alan M____, a significant amount of the firm's work is negotiated or repeat business with private clients, but occasionally they do enter the commercial bid marketplace.

Each partner within the firm is closely involved in the daily operations of the projects they control with little administrative support. The company does have three project managers that the four partners share and may switch from project to project or partner to partner without regard to project boundary. Many of the superintendents are also provided with a significant latitude in terms of how they run a job. In some cases the superintendents work as the Project Manager in terms of hiring subcontractors, scheduling the work, and doing all estimating themselves and only reporting back to the managing partner responsible for that particular client and project.

The firm, while located in Illinois, does work throughout the United States. The company typically will hire subcontractors to do almost all of the work on a project and only provide a superintendent to provide oversight responsibility. On projects where the firm must hire people to perform some part of the work (e.g., carpentry, cleanup) the firm utilizes the services of trade union labor. Because so very few projects involve non-subcontracted Union members, the firm does not track the labor activities of the workers except to record that they worked on a particular project. Consequently, no process model for labor recording was developed.

Level of Computer Use

BBB Construction Corp., while small, is fully networked: most field superintendents are provided laptops to communicate to the office or get information from the network server. Training is provided for using the laptops, but there are still some superintendents that have either not gotten their own laptops or have opted out of receiving one. All project files are maintained on the network and, with the exception of the files in accounting, are accessible to all members of the firm. Actual use of the network and the programs stored on the server varies widely. As pointed out by Alan M____, "we try not to force the guys to use it."

The firm made the decision three years earlier to adopt the use of the Microsoft® Office suite of software tools and Microsoft Project® for scheduling purposes in order to allow for tighter integration between the software packages, but it was revealed that one partner still uses Lotus 123®, an electronic spreadsheet program, exclusively. A second reason provided to the researcher for the use of the common office suite software package was the desire to standardize the look of correspondence, invoices, transmittals etc. through the use of company designed templates. The Domain Expert considered this homogeneity very important. Each member of the firm is trained in the use of the office suite software, and the partners, Project Managers, and Superintendents have all received training in the use of Microsoft Project®.

The company utilizes a specialized accounting software package designed for the construction industry, but access to the software on the network is restricted to the Accounting Department and the President. At the time of this interview, the firm was planning to move more of the cost control aspects (e.g., spreadsheets and variance analysis) of the projects away from the Partners and Project Managers and into the accounting department to provide for better quality control of the information. As pointed out by the domain expert, "because all the information is going through there [accounting] and I always get scared of . . . that someone is keeping score [in project management] that doesn't have all the costs no matter how many reports they look at. . . . There is always something that is missing."

Policies and Procedures

According to the Domain Expert, Alan M____, there is no written policies and procedures manual for the firm. There is a small employee manual that provides information about benefits, but does not go into details about job responsibilities or procedure handling.

Process of Pay Request to Owner

The existing request for payment process, shown in Figure J-1, shows clearly the mixed roles of the Project Manager or Superintendent of the firm. Because the firm's partners encourage an entrepreneurial energy and freedom to the Project Managers and Superintendents developing the correct image of the model for this firm is more difficult than most included in the research. This model is based on a particular project related to the researcher by the Domain Expert. However, future researchers should be forewarned that this situation of entrepreneurial freedom from a centralized control process may be far less than typical in many other construction firms.

At BBB Construction Corp., as shown in Figure J-1, the Superintendent/Project Manger (depending upon the circumstances these positions may be held by the same person) updates the current work schedule to represent the most current job conditions by

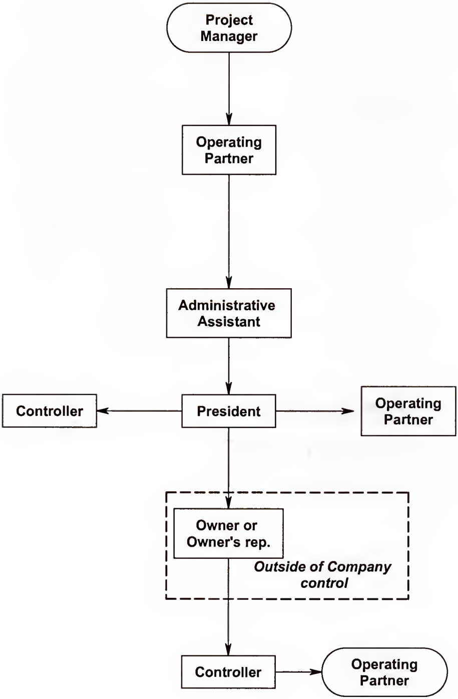


Figure J-1. Model of the "as-is" BBB Construction Corp., payment request to owner process.

verifying the work completed in the field.. The Project Manager assembles the "draw" requests from the subcontractors working on that particular project to put together the monthly request from the owner. This package is then turned over to the Operating Partner that initiated that project for review. Upon completion of review the billing request is given to one of the Administrative Assistants.

The Operating Partner is a title used by the researcher to identify the partner in the firm responsible for that particular project. The Domain Expert, Alan M____, stated that in another firm, these individuals might be labeled "Vice Presidents," but that he honestly "does not remember their titles." The Operating Partner reviews the subcontractor monthly billing request on the project and any notes provided by the project superintendent including an updated schedule. In many cases, because the Superintendent/Project Manger is provided with a significant amount of freedom and trust to act on their own, he/she may be the person actually developing the firm's monthly draw request in addition to approving subcontractor draw requests. The Operating Partner manually completes the draw request and calculates the retainage for the monthly draw.

The monthly billing request is given to one of the Administrative Assistants to be typed and provided to the President for signature and final review. As with the Project Managers, the administrative assistants typically are shared by the Operating Partners depending upon the volume of paperwork being generated by their projects. The President, Alan M____, stated that he must see all paperwork that goes out of the office.

Alan M____ said that after review and signing, he has copies made and provided to both the Controller and the Operating Partner. The Controller has one of the administrative assistants in the accounting department update the job file and the company financial statements. The Operating Partner is responsible for updating his/her job file in addition to mailing the original on to the owner or owner's representative.

Change Order Request Process

Because of the close working relationship that BBB Construction Corporation has developed with many of its clients, many change orders are requested and verbally approved without any required paper trail. Alan M____ related the example of how one national retailer wanted on a particular BBB Construction Company superintendent on all stores the retailer was planning to open that year. "They literally handed us the calendar and said we want him [the BBB company superintendent] in October on this project. Then we want him in Chicago to do this one and this one . . . ."

As a consequence of the close working relationship between BBB Construction Corp. and its clients, the model developed, shown in Figure J-2, is more open and subjective than most. To create the model, it has been assumed that the Change Order is being given to a relatively new or infrequent client of the firm.

Typically, when a sub-contractor or client wants a change order, he/she will contact the Operating Partner directly. The Operating Partner usually handles estimating all of the cost changes, overhead and profit by him/herself. When necessary, sub-contractors that have significant additional work will be asked to provide additional pricing information.

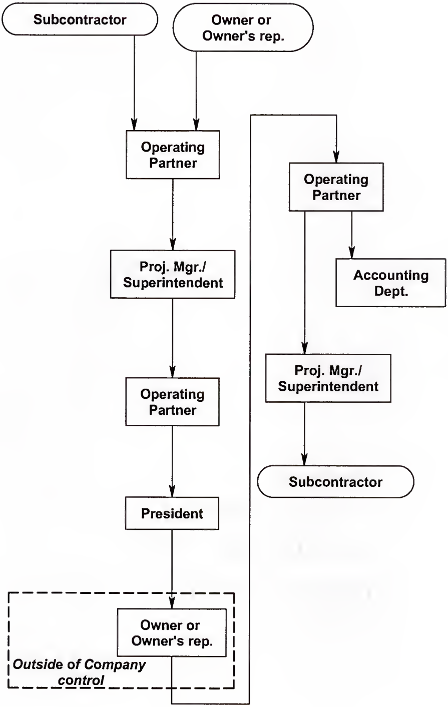


Figure J-2: Model of the "as-is" BBB Construction Corp., request for change order process

The Project Manager assigned to the project will update the Change Order log, which is maintained on the server by an assigned tracking number. The Project Manager may also assist in developing the Change Order by contacting subcontractors or vendors for their changes or assist in estimating the cost of the new work.

The Operating Partner finalizes the change order by putting on BBB Construction profit and overhead costs. The Operating Partner manually writes a new Change Order request on the firm's standardized form and gives this to the President for final review and approval. After review, which is usually cursory according to Alan M____, he has the Change Order typed and transmitted to the Owner's Representative.

Notification of acceptance or non-acceptance of the Change Order from the owner is normally sent directly to the Operating Partner, or the Project Manager will issue change orders to the subcontractors on the project.

APPENDIX K
CASE STUDY OF FLD CONSTRUCTION COMPANY

Introduction

This large US firm does between $150 and $200 million per year in contract volume and is located in the Southeast. The three processes of labor reporting, request for payment by owner, and change order handling were examined as part of this investigation and models of these processes developed. Primarily, FLD Construction Company pursues low bid government or military work, but the firm is increasing the amount of negotiated private, commercial, or industrial work that is handled.

The firm is a closely held, privately owned company. The firm does not have any satellite offices because the President's desire to maintain close contact over company controls. There is a wholly owned subsidiary firm, located in a different state, which specializes in industrial type projects, but it has separate office that was not included in this investigation. The subsidiary firm maintains its own separate accounting and information systems.

The Domain Expert for this case study was the Senior Operations Manager, Alex J_____. Interviews were held with the systems administrator, one superintendent, several project managers, employees of the Accounting department, the firm's Controller, and the Contracts Manager. Three company processes – labor reporting, request for payment, and Change Order reporting – were modeled based upon the information determined from the interviews and validated by the Domain Expert.

Level of Computer Use

The company has several dedicated information systems people that are part of the accounting department, but provide service to the entire firm. The firm uses a network system to link projects with the home office and all superintendents, or the office engineers on large jobs are provided with laptops to transmit information to the home computer. The company maintains its own intranet, and provides training on how to use it. However, project management and superintendents, unlike others in the firm, do not have direct access to the network, but use dial-up accounts. The superintendents primarily use their dial-up accounts to transmit information to the home office computer for payroll information.

The payroll program software was developed in-house specifically for the company. Upper management and construction "support" functions (e.g., estimating, purchasing, accounting, marketing) are networked together, but as discussed earlier, project management and superintendents do not have this capability. The reasons for this lack of direct access were not exactly made clear. When asked about this, several people told this researcher that "its always been that way" or that is was done for "security access reasons." Clients, subcontractors and vendors do not have network access.

Commercially available project management or project scheduling software (e.g., Primavera's P3®, MS Project®, CA-Super Project®) and document management software (e.g., Expedition®, Open Plan®) are available on the intranet. However, it was told to this researcher that, in fact, while training is provided for use of the programs, it has been more of a push by "the younger guys that we have hired out of college" to get superintendents to use the software. "The training efforts have resulted in a mixed bag of use" was how it was described. The information systems manager related the following anecdote to this researcher: "One of our older guys, in his mid fifties, saw what some of the new guys could do and said 'I have to have that!'" New hires are expected to be "computer literate" although they do not necessarily have to have full training on any of the project specific software programs used. According to the systems manager, however, despite the fact the company has offered some training, upper management is still unsatisfied with the level of training provided to the firm's employees as upper management feels the software and hardware are under utilized except in the Accounting department.

The company does not use e-mail or other types of groupware applications, nor any type of expert system. They do make extensive use of relational databases for employee tracking, asset management, financial statement reporting, etc. The firm uses a mix of electronic spreadsheets and specialized software (e.g., Timberline®, MC$^{2®}$, WinEst®) for estimating purposes and training is provided for their use.

Policies and Procedures

Processes and procedures at FLD Construction Company are not written down in a standardized format. The manual available that is provided to employees deals more with company structure and position responsibilities than actual procedures of how things are to be completed. Very little formal training is provided to new hires. Instead, they are "paired" with a Project Manager or more senior Superintendent to learn the ropes. Many of the company's headquarters, senior employees, and superintendents came from a previous firm run by the President of the company. Consequently, many processes that were used in that former firm have been carried over with little or no change in operating procedures to FLD Construction.

Process for Labor Payroll

The process for recording and distributing the labor payroll at FLD construction company, as shown in Figure K-1, starts with the crew foreman, or a Superintendent on a smaller project, recording the activities of each employee on a daily time sheet. This daily time sheet, in turn, is used by the Superintendent to cost code a weekly payroll sheet. The usual process is that the field clerk or Office Manager will also use the daily time sheet after the information has been coded by the Superintendent and enter this

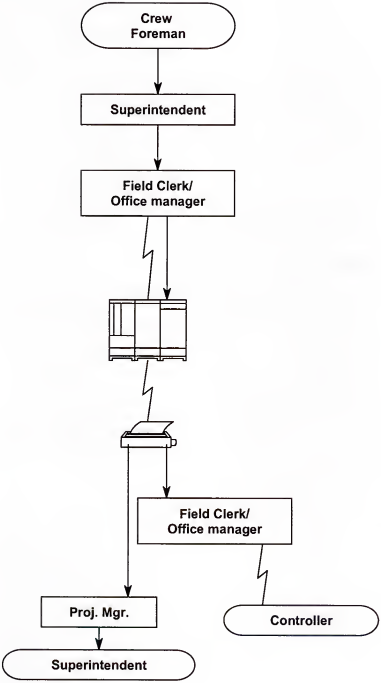


Figure K-1. Model of the "as-is" FLD Construction Company labor reporting process.

information into the payroll system in the home office. This is done on-line, typically every day, so that all payroll information is recorded at the end of the day.

On Mondays, the weekly time sheet is faxed to the office and the field clerk or the Superintendent will call the office to verify the hours sent in on the weekly time sheet and entered during the week directly to the payroll program.

Process of Pay Request to Owner

The monthly payment request to owner process, as shown in Figure K-2, starts with the project Superintendent and the Scheduler providing the Project Engineer the most recent update information. The Superintendent is also responsible for projecting till the end of the month the amount of work that will be billed to the owner so that it can be included on the billing for that month.

The Project Engineer is responsible for synthesizing all of the project information and producing a rough draft of the contract draw amount the company will be billing for the month. This information is given to the Project Manager for review and changes. Once he or she has made any changes he/she feels necessary to the draw amount and breakdown, the Project Manager will key in all of the information into a spreadsheet maintained on the computer network.

The system will generate a series of billing reports for each project that is separated by the someone in accounting and distributed through the office to the respective Project Manager. The spreadsheet program is also designed to calculate cash flow needs and billing summary reports for a specific Project Manager. In addition billing summary reports can be generated for all projects within the entire company. Company wide projects reports are not given to the Project Managers, but are given to the Construction Manager and the Vice President for Operations so that they can track cost information and project progress.

Each Project Manager reviews the spreadsheet output for changes before passing it on to the Construction Manager. The Project Manager prepares a standard cover letter to the owner of the project and signs it.

The Construction Manager provides one final review to the monthly billing for each project. Additionally, he or she will also sign each billing letter and the monthly invoice to the owner as an officer in the company. The Construction Manager is further responsible for making copies of all of the signed documents before mailing them to the owner. The copies of the signed documents are provided to the Contracts Manager who will file them in the job files for the specific project.

Once the Accounting Department has received payment from the project Owner, they are responsible for immediately issuing checks to the project subcontractors and vendors. Additionally, the Accounting Department is charged with updating the job files.

Change Order Request Process

The initiator of any change order may be a subcontractor, the Architect, the Owner's representative or the General Contractor. With FLD construction company, this request for a change order, coming from the field as shown in Figure K-3, is normally

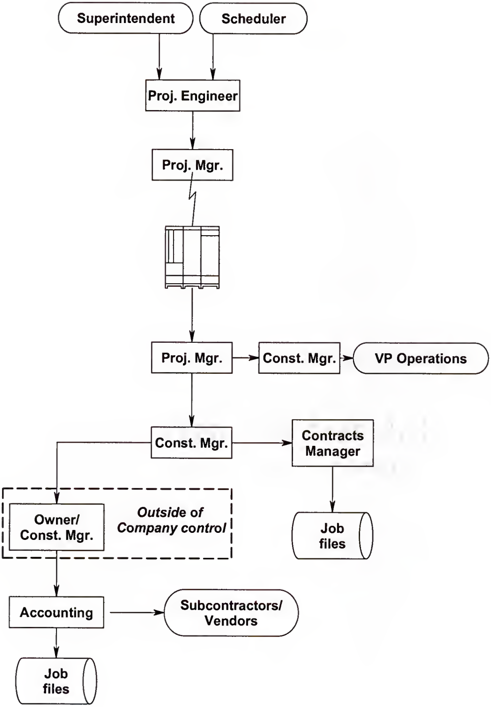


Figure K-2. Model of the "as-is" FLD Construction Company payment request to owner process.

initiated by a field clerk or Superintendent in the jobsite construction trailer. On occasion, this request for change order may be directly transmitted to the Project Manager via a phone call by the Architect or the Owner's representative, but this is not the norm. The field clerk transmits this information to the home office to a specially designated "tracking clerk" in the Contracts department. The Contracts department is responsible for handling writing and revision of all contracts and purchase orders written by the firm. The "tracking clerk" will enter the information into the database set up for that particular job. The program will automatically assign a "tracking number" or "cost control number" for tracking the requested change order through the system.

Concurrent to this process, the field clerk or Superintendent will notify the Project Manager of the desired change in the project. The Project Manager analyzes the job and manually fills in a budget revision worksheet with input from the Project Engineer, subcontractors, and vendors. The title "Project Engineer" is the title given to members of the Estimating and Procurement department. Each project, regardless of size is assigned a Project Engineer although his or her services may not always be required. It should be noted that pricing information by subcontractors and vendors is outside of the company's control process although the firm does exert a strong influence over its subcontractors and vendors.

The Project Manager also notifies the Contracts Manager at the time he/she is requesting pricing information, regardless if it is from internal sources (e.g, the Estimating and Procurement Department) or external sources (e.g., subs and suppliers on that job). The Contracts Manager verifies the Change Order number to the contract and tracks costs to ensure that they are properly accounted for in case of any required contract adjustment. The Contracts Manager, as shown in Figure K-3, also provides copies of the proposed Change Order to the Construction Manager.

The Construction Manager in FLD construction company is responsible supervising the work of all Project Managers, Contracts, and the Planning and Scheduling Department. The Construction Manager only scans the proposed Change Order to ensure there is no legal problems or change in the scope of the contract that must be renegotiated. It was told to this researcher that typically this is merely a cursory review only and that the Construction Manager will not necessarily examine all Change Orders.

Once all information has been collected and a final price for the Change Order determined the requested Change Order is provided to the Owner or the Owner's representative, usually an Architect or Construction Manager. As shown in Figure K-3, the acceptance or rejection of the Change Order is outside of the company's control, but still a part of the entire process.

If the Change Order is accepted, the Project Manager notifies internally both the field Superintendent and the Contracts manager, and externally any affected vendors or subcontractors. The Contracts Manager is responsible for producing Change Orders to the required subcontractors and adjusting their contracts accordingly. The tracking clerk is responsible for filing all Change Orders and contract changes.

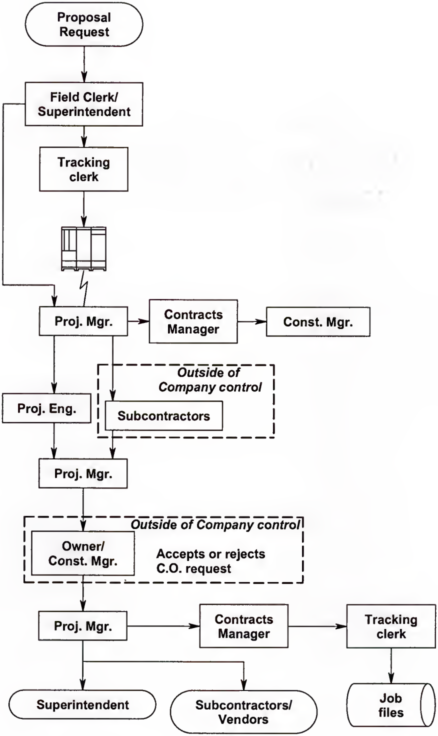


Figure K-3. Model of the "as-is" FLD Construction Company change order request process.

APPENDIX L
CASE STUDY OF CDL CONSTRUCTION COMPANY

Introduction

CDL Construction Company is a Southeastern U.S. based construction company. The pilot case study for this research, CDL Construction Company contracts between 100 and 500 million dollars per year in contract volume. All work is concentrated in a three state area. The firm has no satellite offices. The majority of the work, estimated to be 80%, is by negotiated contract. The remainder of work obtained is through short listed competitive bidding.

In addition to the office personnel and field Superintendents, the firm has approximately fifty full time craft employees in the field. Some of these employees travel from project to project with the Superintendents, but the majority of them are permanently assigned to the construction and maintenance of facilities that belong to some clients of the firm.

The three processes of labor reporting, request for payment, and change orders we were modeled as part of this research. The Domain Expert at CDL was company President, Taylor H____. The company is privately owned and has been in business for approximately 48 years.

Level of Computer Use

CDL Construction Company has developed and maintained its own network system. Just one year previous to this research interview, the company had switched over from a networked Apple system to an IBM mid-frame server. All office employees and Superintendents are networked or have dial-up access capability. All project Superintendents are provided with laptops for their use in updating records and accessing the system.

The firm has purchased and uses project management scheduling software for job tracking. Typically this software is used by Project Managers and Superintendents to control and forecast the progress of work on the job site. The company does not have dedicated schedules so it is imperative that these people using the software are skilled in its use. Training is provided with refresher and update courses every two years or so.

CDL Construction does not use any type of document management software (e.g. Prolog®, Expedition®, Open Plan®); instead, it employs electronic spreadsheets for that purpose. Spreadsheets are also used by the firm for labor forecasting, cost control and estimating.

Database use in the firm is primarily restricted to accounting (for tracking employee work history and subcontractor information) and marketing (tracking clients and job leads). As with all other software used by the firm, training and regular refresher courses are provided in its use.

The firm does make extensive use of e-mail for communication both in the office and to field Superintendents. As discussed earlier, field Superintendents also access the accounting software and upload their payroll. The company uses the Internet for research or to find specialty material or equipment suppliers. Despite the heavy use of e-mail and the Internet, the company does not provide dial up access to its subcontractors or clients. According to the one project manager interviewed, "many of our subcontractors don't have fax machines much less a computer."

Policies and Procedures

The company has developed a very comprehensive policies and procedures manual that is provided to all office employees and field Superintendents. Each procedure is clearly explained, and sample copies of completed forms are provided along with instructions on how to fill them out.

The company's policies and procedures are also undergoing an internally developed Total Quality Management (TQM) review by upper management. The firm's President, recognizing the importance of quality to his clients, has used the firms TQM initiative to improve all areas of the business. Several members of company upper management have received formalized training in TQM and are currently acting as facilitators to train the rest of the firm.

As part of the TQM initiative, the firm has begun to develop its own process models for its internal processes. Of the three processes under study as part of this research (Labor reporting, change order process, and request for payment), only the change order process had been modeled by the CDL Construction Company's TQM project champions. The Change Order process model developed by this researcher was created independently of CDL Construction's modeling effort.

Process For Labor Payroll

The Domain Expert, Taylor H_____, when asked about who "owned" the Labor Payroll process, stated without hesitation, "the project Superintendent." Project Superintendents are required to record daily the work activities of all CDL Construction Company employees. A standardized electronic company form is completed by each Project Manager while they are online with the payroll software program. This process is shown in Figure L-1.

The program automatically updates the labor accounts in the project budgets. Each Project Manager is responsible for maintaining his/her own project costs. These are updated weekly.

The software program automatically calculates withholding, rate of pay, etc. The checks are printed out in sequence by project. The Controller is responsible for inspecting all checks before signing them. The checks for employees are always kept sorted by project and Project Manager.

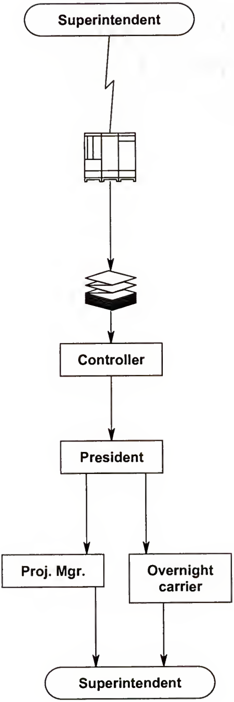


Figure L-1. Model of the "as-is" CDL Construction Company labor payroll process.

Each Project Manager is given the envelopes containing the checks for their projects except where the checks must be delivered by commercial overnight carrier to the project Superintendent for distribution because the project is geographically far away.

The Project Managers are responsible for hand carrying the employee payroll to their respective projects during their weekly inspection and review visits. When a Project Manager is out of the office visiting a remote site or on vacation, another Project Manager or the President will take out payroll to the project superintendent. Because of the requirement by the company that the Project Manager deliver the payroll, there is a one week delay from the time of reporting until employees are paid.

When asked about other controls that exist in the payroll process, the Domain Expert, Taylor H_____ shied away from commenting. Others in the firm indicated that occasionally the President will review the payroll.

Request for Payment

The monthly request for payment at CDL typically begins around the 20th. The Project Manager, as shown in Figure L-2, creates a list of the schedule of values for the project. In consultation with the Superintendent, the Project Manager updates the schedule of values to accurately reflect the actual work completed to date. Together they work to develop a projection of work that will be completed by the end of the month.

Concurrent to this, the Contracts Assistant is to contact all subcontractors and have them forward their monthly request for payment to the owner. The Project Manager reviews the subcontractors monthly requests along with a summary of material purchases for the projects forwarded by the CDL Accounting department. The Project Manager also reviews the Change Order log for any approved change orders that can be billed.

Once the Project Manager has collected the information and written the monthly request for payment to the owner, it is given to the Contracts Assistant to type. Once typing is completed, it is returned to the Project Manager for review. The Project Manager checks the invoice for proper documentation and signs it. The Project Manager is to make two copies. One copy is provided to the CDL Accounting department. The second copy is given to the Contracts Assistant for updating the project pay request log. The original is sent to the Owner's representative (e.g., Architect or Construction Manager) or the Owner for approval and payment.

Once payment is received the Project Manager is responsible for updating the project pay request log and notifying the Accounting department to issue and release checks to project subcontractors and some specific vendors.

Change Order Process

The Domain Expert, Taylor H_____, stated that "typically the majority of our change order requests come from the architect on a project or subcontractors. We or our suppliers generate very few... maybe twenty percent at most." Each of these sources triggers the Project Manger to manually log in the requested change in the projects' change order proposal bag as shown in Figure L-3. Depending on the size and scope of the proposed change, the Project Manager will consult with the Superintendent in addition to contacting subcontractors for their pricing and scheduling information.

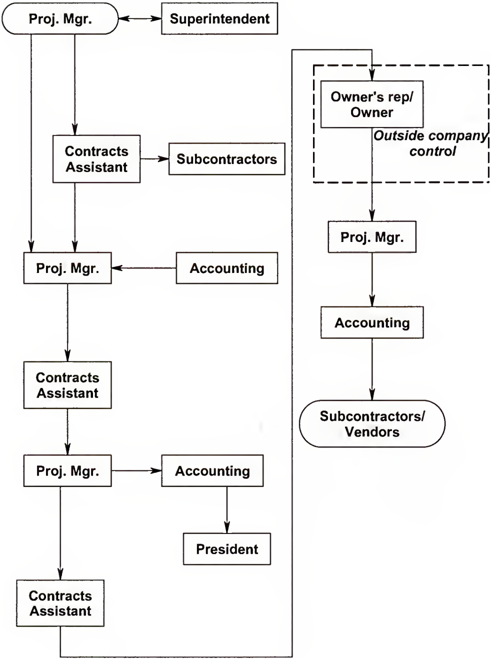


Figure L-2. Model of the "as-is" CDL Construction Company request for payment process.

The actual change order proposal is written up by the Contracts Assistant, the equivalent to an Assistant Project Manager, in another office. Each Project Manager is assigned one Contracts Assistant that assists the Project Manager in areas like writing contracts, estimating work, and scheduling development.

The Project Manager, as shown in Figure L-3, will review the Change Order request, then return it to the Contracts Assistant for distribution to the Owner's rep and the Owner for review and approval. The time for the process from initiation until Owner review, on average, is estimated to be ten days. The firm has a policy against delaying Change Order requests to ensure the work on the project site is not delayed.

Once a Change Order has been approved, a ripple effect of actions occurs. First the Project Manager will update the manual Change Order proposed log. The Project Manager will also contact the Superintendent and Contracts Assistant about the approved Change Order. The Project Manager will update the budget and notify Accounting of the budget change.

The Contracts Assistant will propose changer orders for each of the subcontractor or vendors. These are presented to the Project Manager for review and approval before being sent out by the Contracts Assistant. Additionally any revisions to the schedule will be prepared by the Superintendent and sent out with the changer orders or contract modifications.

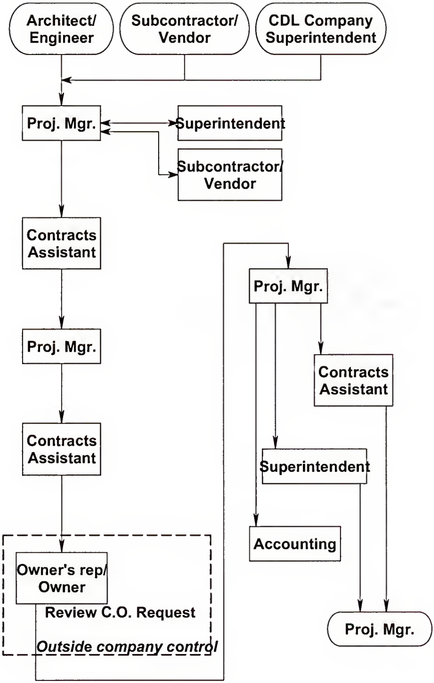


Figure L-3. Model of the "as-is" CDL Construction Company change order request process.

APPENDIX M
PQR CONSTRUCTION COMPANY CASE STUDY

Introduction

PQR Construction Company, located in the Midwest, has worked its way onto the *Engineering News Record* 500 by managing approximately 100 million dollars plus in new construction over the past two years. The three processes examined as part of this research were PQR's labor reporting process, request for payment, and Change Order process. Each of these processes were modeled by conducting a series of interviews with company President, John H_____, the Domain Expert for this case study. In addition, members of the firm's project management staff and field personnel were consulted.

Privately held PQR Construction Company has built its business by developing long term business relationships with national companies, like movie theaters, insurance, and banking, and by traveling to where the clients want to build. Roughly 70-80 % of PQR Construction's business is either negotiated or from repeat clients. The other 20-30% of their business is hard bid contracts for schools, churches, and other institutional, non-residential structures.

The firm maintains two other branch offices in addition to its home office and, at the time of the research visit, were looking to open one more branch office in the far west. One satellite office was investigated as part of the research in addition to the home office. The branch offices function as an extension of the headquarters office and mirror the head office.

Level of Computer Use

Currently PQR Construction has one full time out-sourced contract employee responsible for maintenance of the company's hardware and network systems. Most of their hardware is from a single source with the vendor responsible for upkeep of the system. Additionally, the firm had begun a program to have all of the job sites provided with laptops for Superintendent's to use, but had not started distribution at the time of the interviews.

In terms of software use or development, PQR Construction makes very heavy use of spreadsheet applications and templates that it has developed internally. Applications of document tracking, equipment maintenance, and estimating concrete formwork spreadsheets were shown to the researcher. Project Managers and members of upper management have access to a number of powerful cost control spreadsheets the firm has created, or contracted, available to them on the company network.

The firm does not use any type of electronic groupware application, instead choosing to rely on fax transmission of paperwork between the jobsite office and the Project Manager's office location, although with the distribution of laptops for field Superintendents, that this may change. Internal collaborative work on documents (e.g., spreadsheets) was found to occur by employees connected to the network for labor reporting.

The company makes extensive use of databases for equipment management, logistics support and, in the Accounting department, for a number of applications. The firm did not use any off-the-shelf document management software program, but chose to use spreadsheet database templates it had developed over time for that purpose.

Because of the firm's heavy use of spreadsheets and databases, it has invested heavily in training for each of its employees. Each employee had received a minimum of 10 hours of training in the use of electronic spreadsheets. New employees were required to take the course as part of their first sixty days with the company. Additionally, the firm had started training employees, beginning with Superintendents and Project Managers, in a "Fundamentals of E-mail" course developed and offered by a local community college.

Policies and Procedures

The firm has a formal policies and procedures manual that is designed to cover virtually all employees and their activities. The firm had just completed a two year program conducting an internal self-analysis of policies and procedures that it uses to run operations and conduct business. This self analysis was required by a major manufacturing client of the company as part of the client's Total Quality Management efforts.

Additionally, all newly hired employees, regardless of previous construction experience, are required to attend a series of training sessions or workshops to learn about software and company positions. Management track employees are transferred between Operations (Field Supervision), Accounting, and other units within the firm every two years for them to learn about all aspects of the business.

According to John H_____, the company works actively to identify and promote "rising stars" by giving them the opportunity to manage smaller (2-3 million dollar) projects on their own with a minimum of direction or interference within three to five years of joining the firm. He suggested that this group of "younger super talented guys and gals" may "set the rule book aside" in the pursuit of completing the job.

"As-is" Process for Labor Reporting

At PQR Construction, the Project Superintendent is required to very carefully record and code labor activities in terms of the project estimate. As shown in Figure M-1, typically PQR Superintendents use a standardized crew of employees rather than assigning tasks to individuals for completion. PQR finds that assignment of tasks to a crew that works together for the length of a project increases their employees' productivity in addition to providing better historical estimate data.

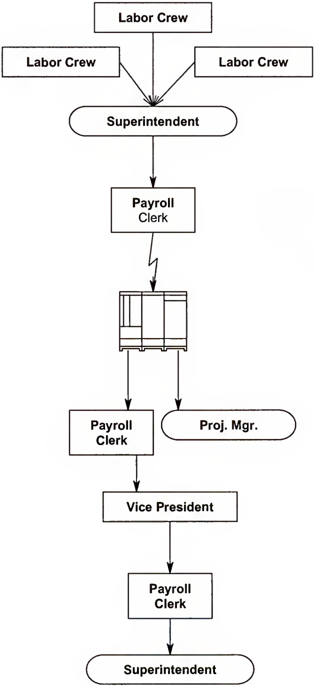


Figure M-1. Model of the "as-is" PQR Construction Company labor payroll process.

Superintendents are responsible for manually completing a time sheet which, depending upon the location of the project, is carried or faxed to the office responsible for that project. Satellite offices produce their own payroll accounts for projects that are assigned to them or are being run from one of the satellite offices. The company runs multiple payroll systems John H____ stated, because the satellite offices were from acquisitions the company had made some years back and that he had found it easier not to consolidate their operations.

Once the weekly time sheets have arrived in the office, they are given to a designated clerk in the Accounting Department responsible for Payroll entry. This person will enter into the payroll software program the weekly time and activities of all field employees. The main office is currently experimenting with having time sheet scanned in to expedite payroll entry.

Once payroll has been entered into the program, typically it is reported by Tuesday at noon, the computer will generate weekly labor cost reports for each Project Manager. These reports are on the network so that members of upper management can also review weekly summaries if they choose for any particular project.

Checks and copies of the project labor summaries for the project files are printed out on Wednesdays. The Payroll clerk is responsible for both sorting checks by project and maintenance of the project files. Currently, despite the fact that backup systems are used, the firm requires that all payroll records have a paper copy produced and stored as part of the permanent record.

At each office, either the Vice President or an Office Manager will sign the payroll checks for employees. These signed checks are handled only by the payroll clerk in Accounting who is responsible for shipping them to the field for distribution.

Payment Request to Owner Process

At PQR Construction Company every payment request to the owner, as shown in Figure M-2, is reviewed by two people before it goes out the door. The Project Manager for the job is the first. He/she will develop the pay request based upon the information provided from the project Superintendent. Additionally, all purchase orders presented for payment during the month and invoices presented for subcontracted work will be given to the Project Manager for review and inclusion in the pay request to the owner.

The second person reviewing the monthly Payment Request is the Senior Project Manager. Each office has a Senior Project Manager, a long term veteran of the company, responsible for overseeing several project managers. The Senior Project Manager has the discretionary power to increase the amount of money being billed to the client. Typically, the Senior Project Manager is the point of contact for PQR Construction with their clients providing "hand holding" for the more anxious clients in addition to providing guidance or advice for Project Managers.

Once the company has received payment, it is the job of the controller in each office to post the payments and update the project budgets. The Domain Expert, John H____, stated that the Controller must be the one to post payment and not another employee of Accounting Department because early on in the company's history some payments had been embezzled.

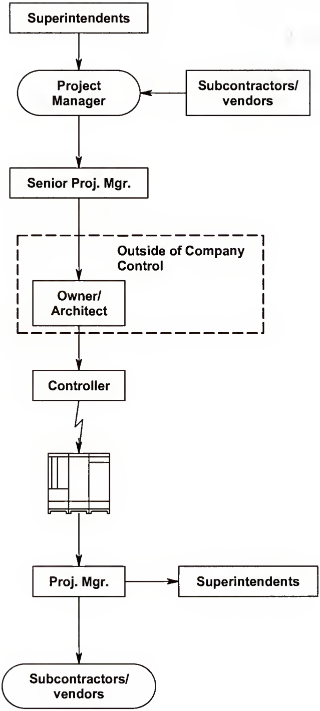


Figure M-2. Model of the “as-is” PQR Construction Company payment request to owner process.

Once the project payments have been received, a "posting sheet" is manually delivered to all of the Project Managers within the office to notify them. Each Project Manager uses the information from the posting sheet to determine payment authorization and update his/her Project Superintendents.

Change Order Process

The Change Order request process at PQR Construction Company begins with the Project Manager as shown in Figure M-3. Once the Project Manager has decided to pursue the Change Order, he/she will have his/her Assistant Project Manager log the request which formally indicates that the firm will ask for time or money change in the contract. The Assistant Project Manager position at PQR is the entry level position for all management employees that the firm hires.

The Assistant Project Manager is put in charge of estimating the costs involved in the Change Order and getting subcontractor and vendor pricing information. Once the Assistant Project Manager has priced out the change order and added in profit and overhead for PQR, the Change Order is given to the Project Manager for review and approval. Once the Project Manager completes his/her review, the Change Order is given to the Senior Project Manager for one last review. Once this review is completed, the Change Order request is returned to the Assistant Project Manager to mail to the Owner's representative for review and approval.

If the Change Order request is rejected, the Project Manager will make a decision on whether or not to revise the Change Order request. If the decision is in the affirmative, then the process starts all over again. If the decision is in the negative, then the Assistant Project Manager files the rejection notice in his/her daily log.

As can be seen in Figure M-3, if the Change Order is accepted, then the Project Manager will notify the Senior Project Manager, Project Superintendent and the Assistant Project Manager who is responsible for updating the log. The Project Manager will also revise or issue new Change Orders or contracts for vendors and subcontractors working on the project.

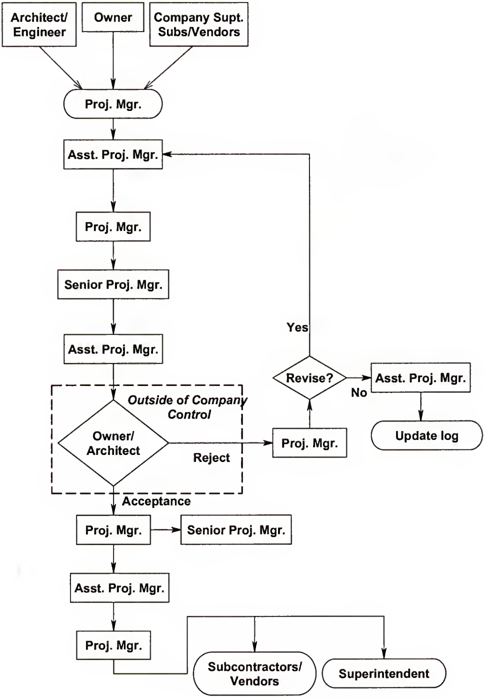


Figure M-3. Model of the "as-is" PQR Construction Company change order request process.

APPENDIX N
COMPARISON VIEWS OF “AS-IS” AND “TO-BE” PROCESS MODELS

This appendix contains side by side model views of the developed process models of the processes examined at each company and the reengineered process after the implementation of expert system controlled workflow. The “to-be” models are based on the generic models developed as part of the analysis of the information presented in Chapter 4. The models are presented without commentary and are presented by process and case study.

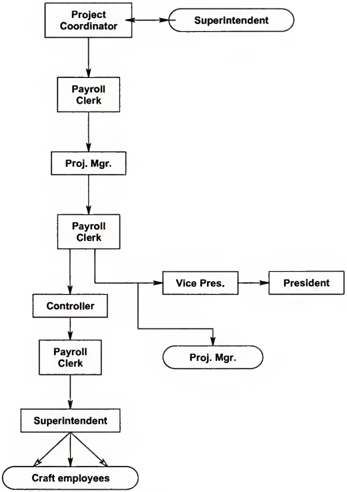


Figure F-1. Model of the “as-is” EDO Construction Company labor reporting process.

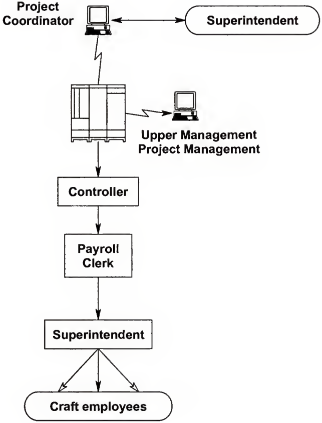


Figure N-1. Model of the “to-be” EDO Construction Company labor reporting process.

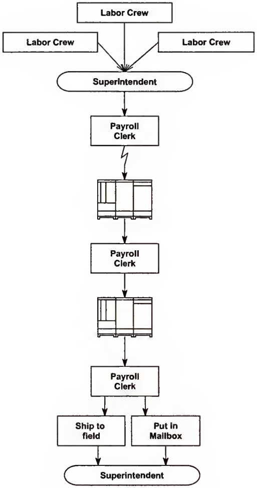


Figure G-1. Model of the "as-is" ABC Construction Company labor payroll process.

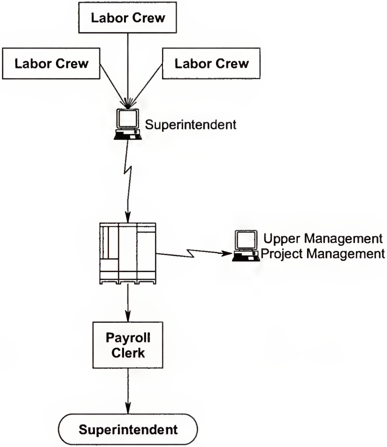


Figure N-2. Model of the "to-be" ABC Construction Company labor payroll process.

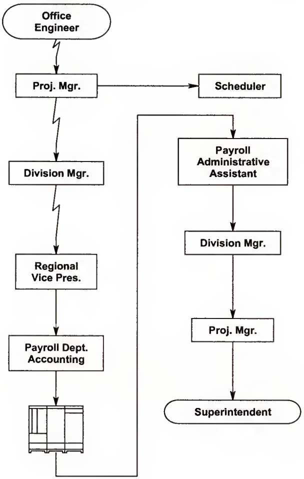


Figure H-1. Model of the "as-is" XYZ Construction Company labor reporting process.

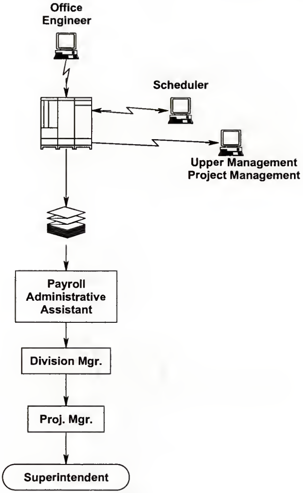


Figure N-3. Model of the "to-be" XYZ Construction Company labor reporting process.

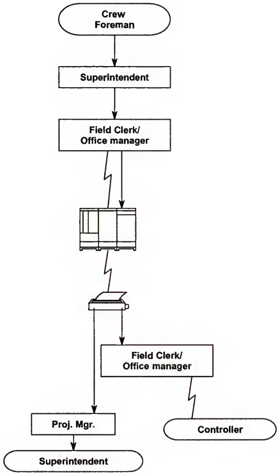


Figure K-1. Model of the “as-is” FLD Construction Company labor reporting process

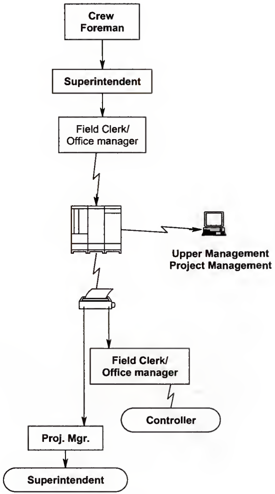


Figure N-4. Model of the “to-be” FLD Construction Company labor reporting process

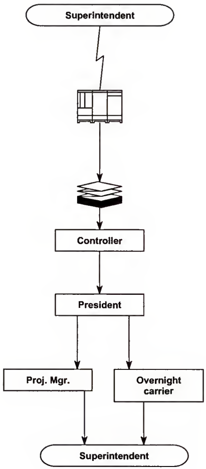


Figure L-1. Model of the "as-is" CDL Construction Company labor reporting process.

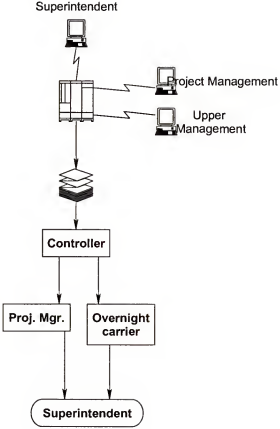


Figure N-5. Model of the "to-be" CDL Construction Company labor reporting process.

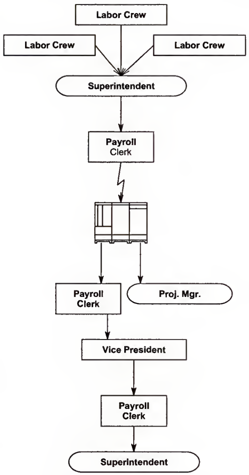


Figure M-1. Model of the “as-is” PQR Construction Company labor reporting process.

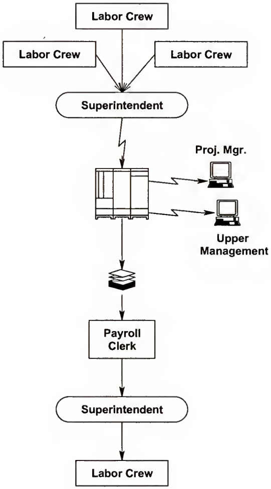


Figure N-6. Model of the “to-be” PQR Construction Company labor reporting process.

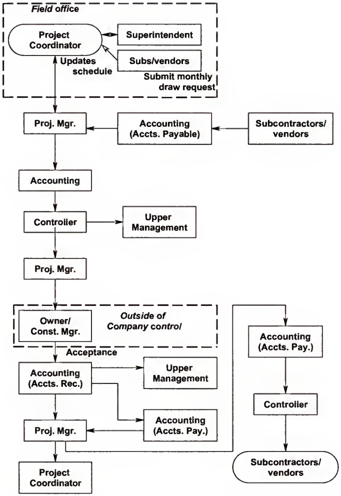


Figure F-2. Model of the "as-is" EDO Construction Company payment request to owner process.

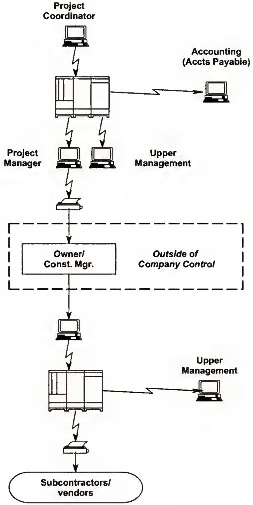


Figure N-7. Model of the "to-be" EDO Construction Company payment request to owner process.

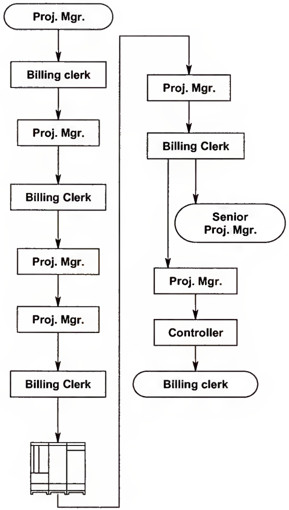


Figure G-2. Model of the "as-is" ABC Construction Company payment request to owner process.

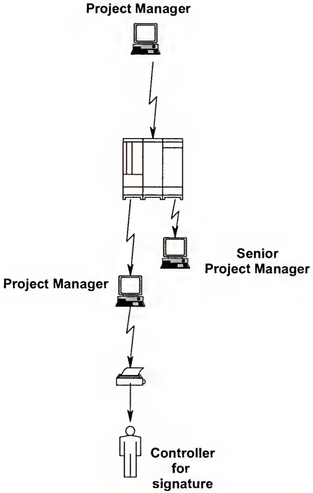


Figure N-8. Model of the "to-be" ABC Construction Company payment request to owner process.

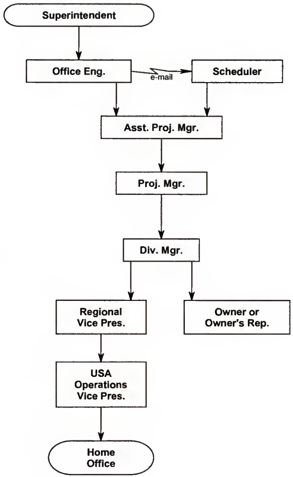


Figure H-2. Model of the "as-is" XYZ Construction Company payment request to owner process.

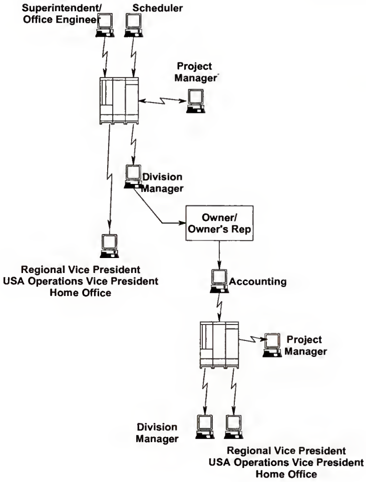


Figure N-9. Model of the "to-be" XYZ Construction Company payment request to owner process.

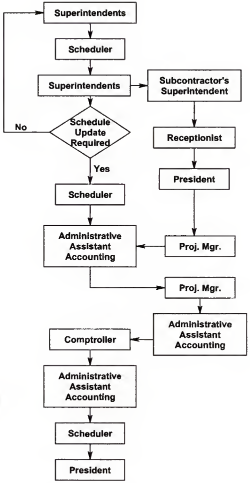


Figure I-1. Model of the "as-is" Q and Q Construction, Inc., request for payment process.

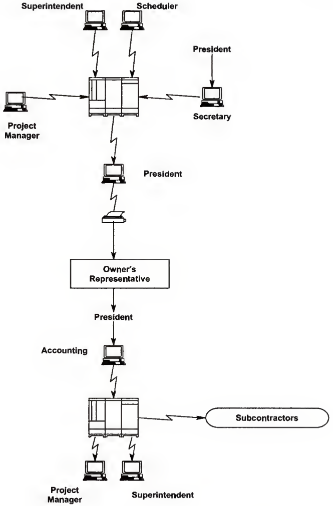


Figure N-10. Model of the "to-be" Q and Q Construction, Inc., request for payment process.

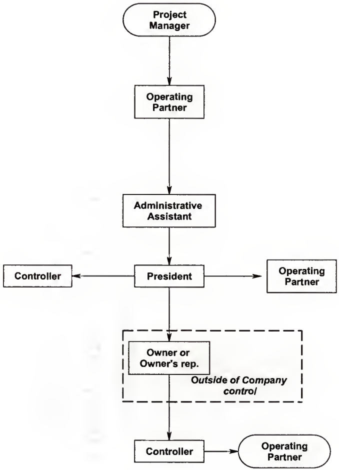


Figure J-1: Model of the "as-is" BBB Construction Corp., payment request to owner process.

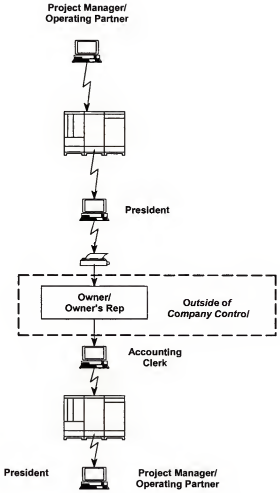

Project Manager/ Operating Partner
President
Owner/ Owner's Rep
Outside of Company Control
Accounting Clerk
President
Project Manager/ Operating Partner

Figure N-11. Model of the "to-be" BBB Construction Corp., payment request to owner process.

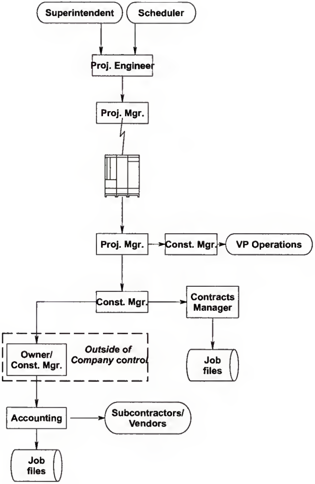


Figure K-2. Model of the "as-is" FLD Construction Company request for payment process.

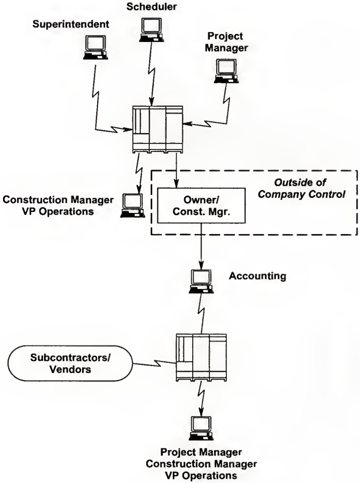


Figure N-12. Model of the "to-be" FLD Construction Company request for payment process.

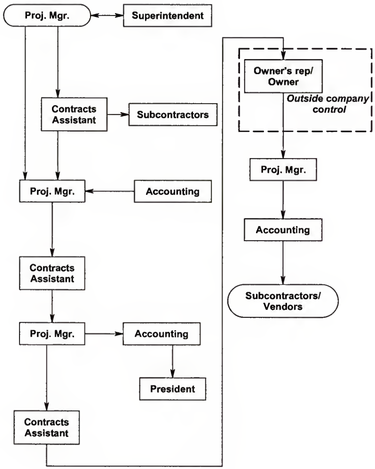


Figure L-2. Model of the "as-is" CDL Construction Company request for payment process.

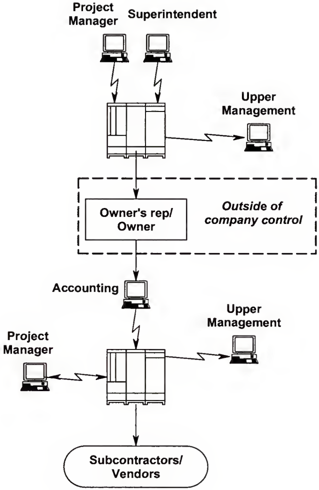


Figure N-13. Model of the "to-be" CDL Construction Company request for payment process.

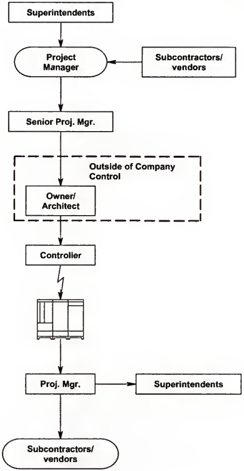


Figure M-2. Model of the “as-is” PQR Construction Company Request for payment process.

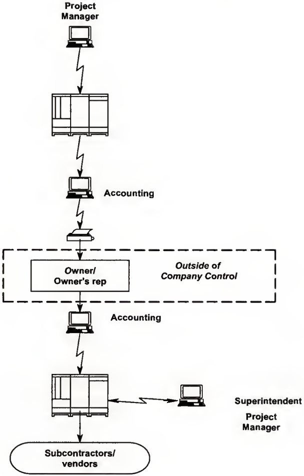


Figure N-14. Model of the “to-be” PQR Construction Company request for payment process.

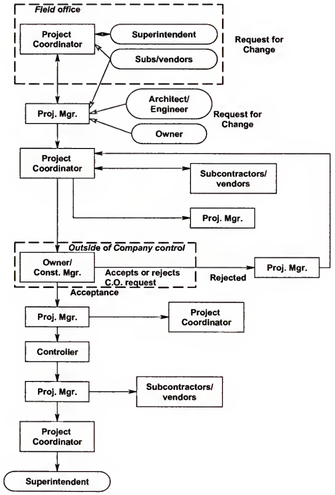


Figure F-3. Model of the "as-is" EDO Construction Company request for change order process.

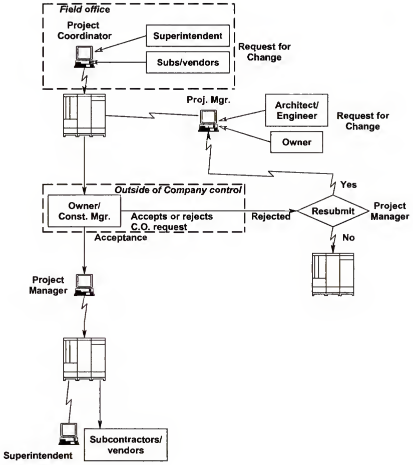


Figure N-15. Model of the "to-be" EDO Construction Company request for change order process.

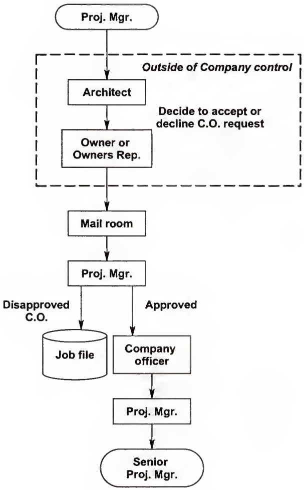


Figure G-3. Model of the "as-is" ABC Construction Company request for change order process.

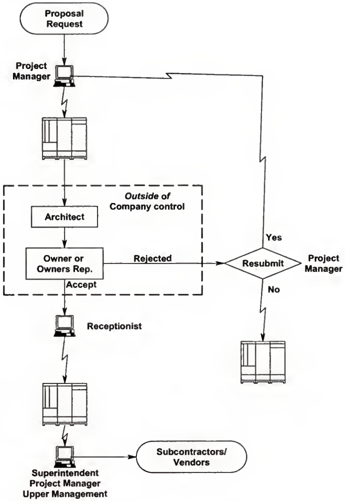


Figure N-16. Model of the "to-be" ABC Construction Company request for change order process.

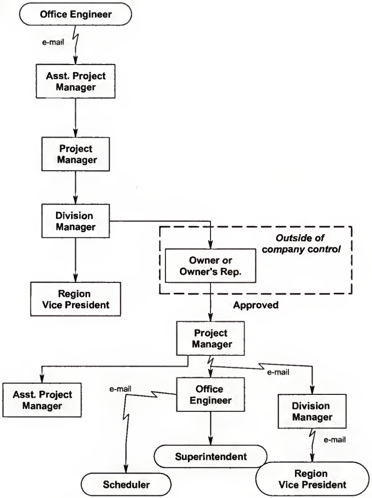


Figure H-3. Model of the "as-is" XYZ Construction Company request for change order process.

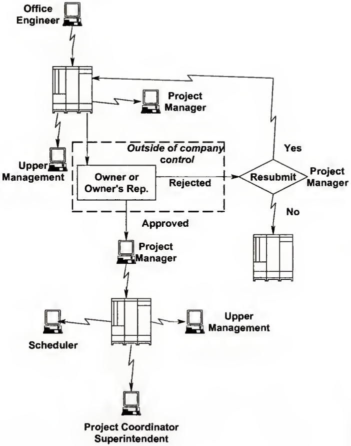


Figure N-17. Model of the "to-be" XYZ Construction Company request for change order process.

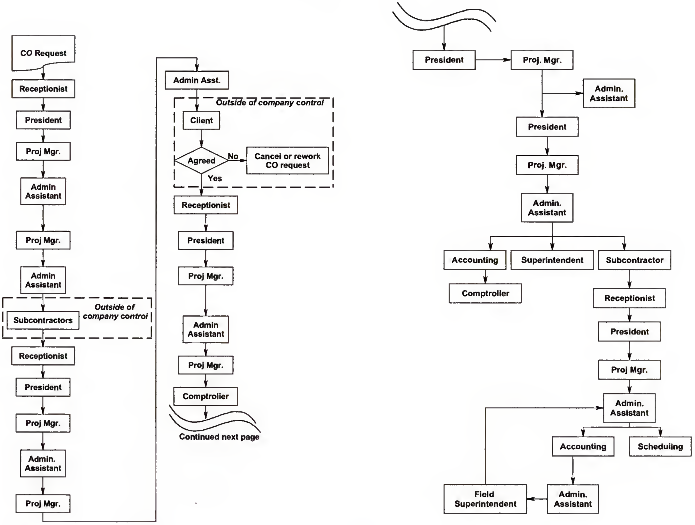


Figure I-2. Model of the "as-is" Q and Q Construction, Inc. request for change order process.

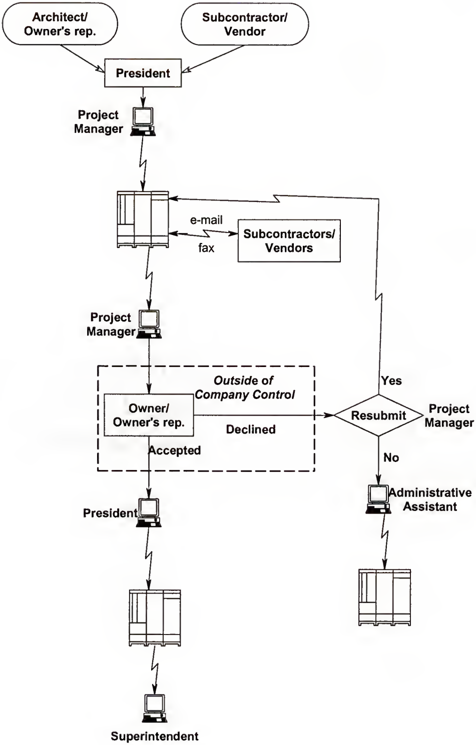


Figure N-18. Model of the "to-be" Q and Q Construction request for change order process.

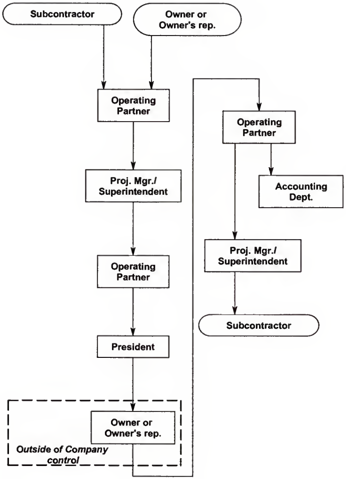


Figure J-2. Model of the "as-is" BBB Construction Company request for change order process.

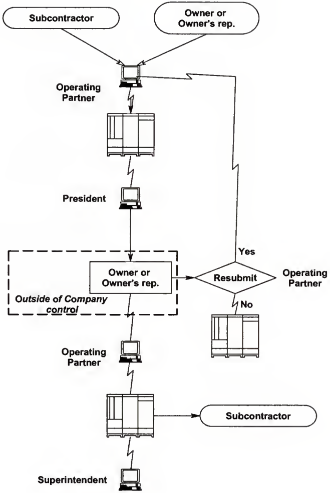


Figure N-19. Model of the "to-be" BBB Construction Company request for change order process.

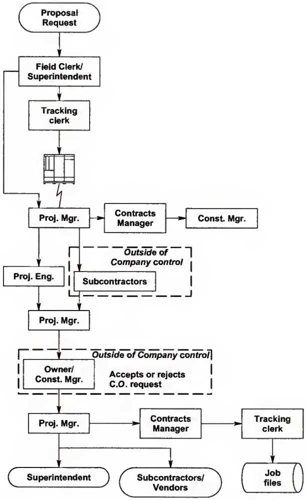


Figure K-3. Model of the "as-is" FLD Construction Company change order request process.

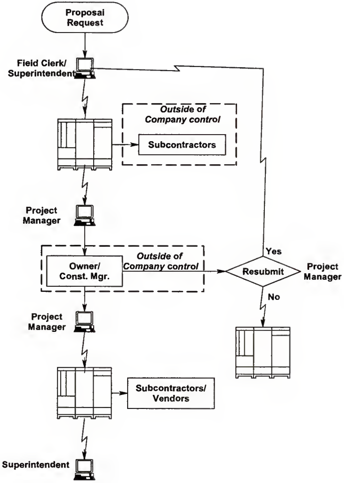


Figure N-20. Model of the "to-be" FLD Construction Company change order request process.

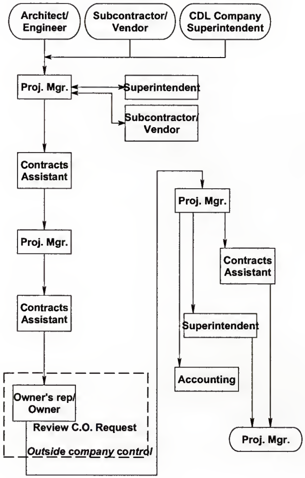


Figure L-3. Model of the "as-is" CDL Construction Company change order request process.

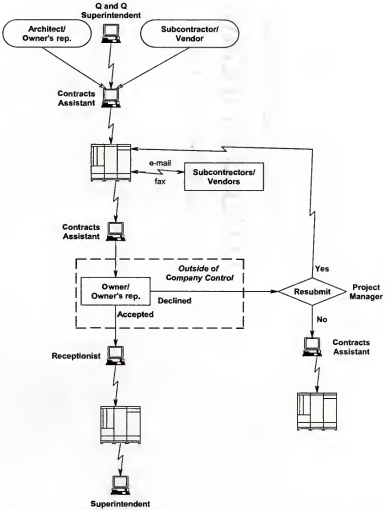


Figure N-21. Model of the "to-be" CDL Construction Company change order request process.

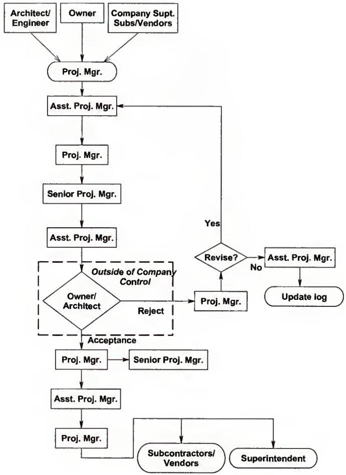


Figure M-3. Model of the "as-is" PQR Construction Company change order request process.

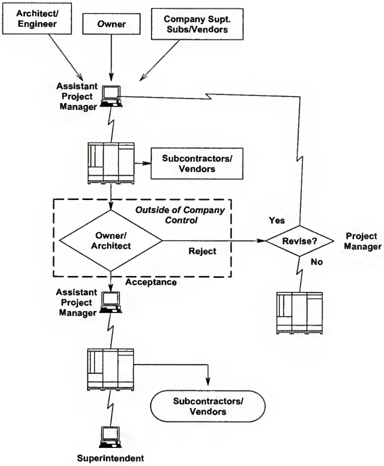


Figure N-22. Model of the "to-be" PQR Construction Company change order request process.

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BIOGRAPHICAL SKETCH

Charles has called St. Petersburg, Florida, his home since moving there in his early teens. After graduation from high school in 1977, he attended the University of Arizona and St. Petersburg Junior College. While working on his degree, he worked for Thompson Construction Company as an estimator and assistant project superintendent. He then went on to several other more responsible positions in the construction industry, eventually resigning to return to school to complete his undergraduate degree in construction management at Florida International University in Miami in 1991.

He then founded Wells, Duvel and Associates, a construction management firm, in St. Petersburg, Florida, in 1992. In 1993, Duvel left Florida to attend Clemson University and work on his master's degree in construction science and management, which he received in 1994.

In January of 1995, he enrolled in the Ph.D. program in building construction in the College of Architecture at the University of Florida, Gainesville. He worked as a teaching assistant responsible for teaching a variety of classes from estimating to construction techniques.

Charles Duvel serves as an assistant professor in the department of industrial technology at Illinois State University, Normal, Illinois, where he teaches courses in the construction management sequence and continues his research in applying workflow to construction management processes.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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